ZAATS

Zebra Advanced Asset Tracking System

Deployment Guide

MN-003194-02EN

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Revision History

Changes to the original guide are listed below:

Change	Date	Description
-01 Rev A	4/2019	Initial Release
-02EN Rev A	3/2020	- Updated minimum server requirements. - Updated ATR installation procedures and post installation integration of ATR7000 with CLAS software. - Other minor enhancements and clarifications.

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About This Guide

Introduction

This guide provides a comprehensive overview of how to ensure a successful deployment of Zebra's Advanced Asset Tracking System (ZAATS) comprised of ATR7000 RTLS overhead readers and Configuration and Analytics Software (CLAS.)

The objective of this document is to describe the requirements and use case definition, detailed system design process (including site survey), installation of reader and networking hardware, and post-installation validation of the ZAATS system. Details of server and software installation are covered in the CLAS Server and Software Installation Guide, and programming information to support application development are covered in the CLAS API Developer Guide.

Chapter Descriptions

Topics covered in this guide are as follows:

- ZAATS Introduction provides an overview of Zebra's Advanced Asset Tracking System, including ATR7000 overhead RFID readers and CLAS (RTLS Services) software.
- Deployment Overview provides an overview of the ZAATS deployment process.
- Requirement Definition defines the first steps in the deployment process, including team roles and responsibilities, and defining the identification and location use cases and overall system requirements.
- Preliminary System Design provides a comprehensive overview of the steps that lead to a complete pro-forma definition of the system, including reader coverage, network design, tag selection, developing the site map, Equipment Manifest, and bill of materials.
- Site Survey describes the steps and guidelines on how to perform an effective site survey.
- Completing the Final System Design describes the steps involved to finalize the pre-installation site map and bill of materials based on the results of the site survey.
- Installation of CLAS Server Software references the Zebra documentation used to install CLAS (RTLS Services) software.
- Installation of ZAATS Reader and Network Hardware provides the detailed steps involved in hardware installation and how to ensure the reader and network hardware is fully functional.
- Post-Installation ZAATS Validation provides the detailed steps involved to ensure ZAATS can locate and track items and is ready for handover to an end user.
- Appendix: Tools and Resources lists some helpful resources that can aid in the deployment of ZAATS.
- Appendix: Leica 3D Instructions for ATR7000 describes the steps on how to use Leica 3D DISTO for the ATR7000 installation.

- Appendix: RFID Tag Board for ATR7000 Installation and Validation provides guidelines on tag placement to test an ATR performance after installation.

Related Documents

The following documents provide more information about ZAATS.

- ATR7000 Advanced Array RFID Reader Integration Guide, p/n MN-003191-xx
- RFID Demo Applications User Guide, p/n 72E-160038-xx
- RTLS Demo Application User Guide, p/n MN-003509-xx
- CLAS API Developer Guide, p/n MN-003198-xx
- CLAS Server & Software Installation Guide, p/n MN-003197-xx
- ZAATS Tag Data & Numbering Guide, p/n MN-003199-xx

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ZAATS Introduction

Introduction

Zebra's Advanced Asset Tracking System (ZAATS) provides continuous identification, location, and tracking of items tagged with passive UHF RFID tags conforming to the GS1 EPC™ Radio Frequency Identity Protocols Generation-2 UHF RFID Specification for RFID Air Interface standard. ZAATS is designed to enhance the efficiency and work-flows of Zebra's customers' operations, which are increasingly focused on cohesive, real-time data.

ZAATS consists of two primary components: the Real-Time Location System (RTLS) Services software, which contains the configuration, management, and location analytics components; and the ATR7000 overhead array readers.

Product Overview

Description and Features

ZAATS is a passive UHF RFID based asset tracking solution developed primarily for indoor warehousing, manufacturing, and logistics applications. It is based on the ATR7000 overhead RFID reader containing Zebra's proprietary advanced array architecture with integral antenna capable of steering beams and estimating the bearing to RFID tagged items with unprecedented accuracy and speed.

A summary of the key system and product features of ZAATS includes:

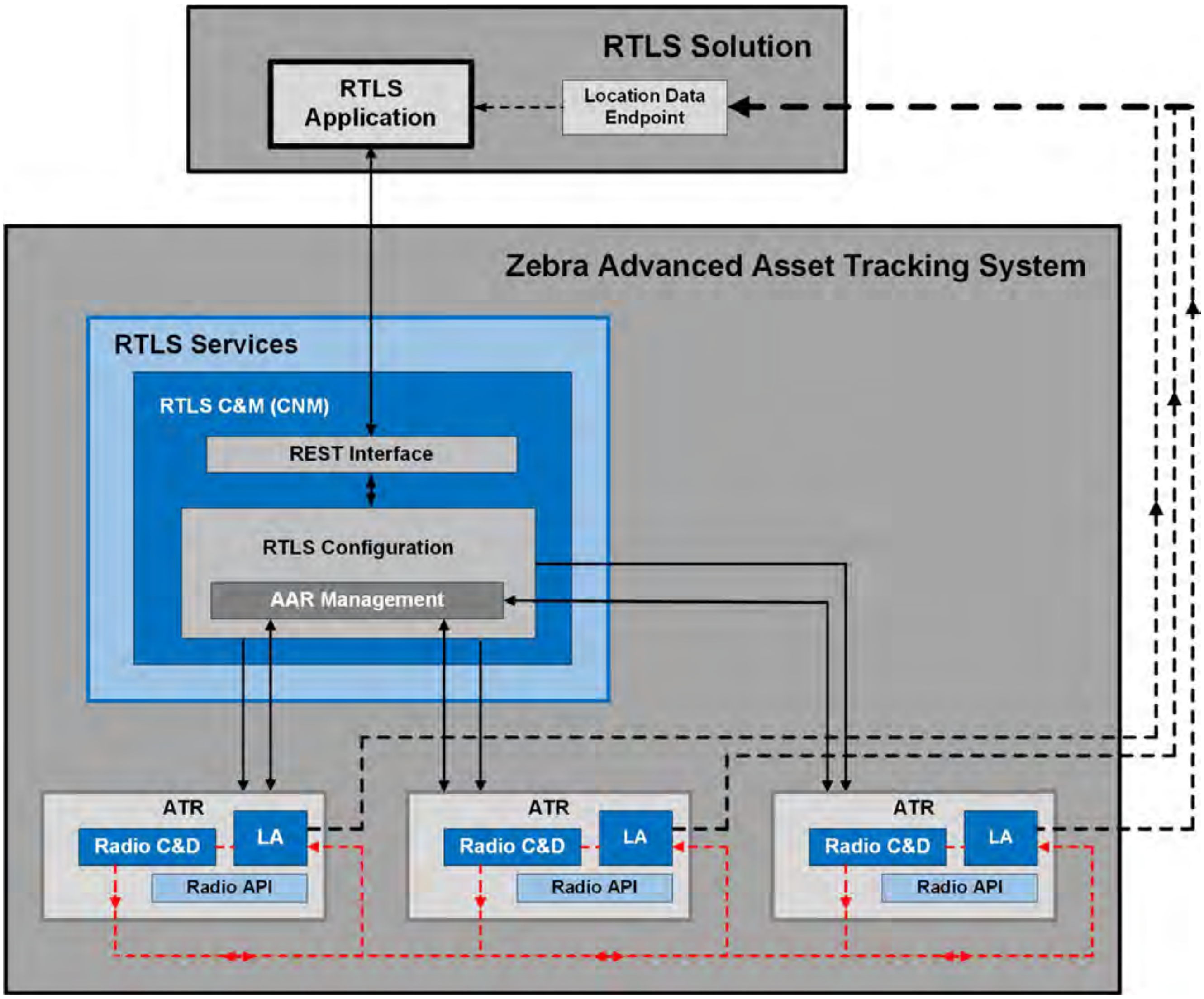
- A passive UHF RFID RTLS system that provides real-time identification and location data of tagged items for continuous asset monitoring.
- Configuration and Location Analytics Software (CLAS) that configures, controls, and manages the system, as well as a high-performance location analytics engine capable of providing up to 100,000 (1000 readers at 100 tps) tag location estimates per second with 2 ft typical accuracy.
- APIs to configure, manage, and control the ZAATS system using an HTTP-based RESTful interface.
- Docker container virtualization to simplify integration and deployment into end-user and partner applications.
- Software tools and documentation to facilitate system installation, including site planning, calibration, initial start-up, and deployment validation testing.

NOTE: Configuration and Location Analytics Software (CLAS) is needed to run RTLS Software. Configuration and Location Analytics Software (CLAS) is synonymous with RTLS Services software. The two terms are used interchangeably throughout this document.

Figure 1 illustrates the high level architecture of the ZAATS system showing the two main components of the ZAATS system:

- AARs (ATR7000 Advanced Readers)
- RTLS Services software.

Figure 1 Zebra Advanced Asset Tracking System (ZAATS)



In Figure 1, the solid lines correspond to configuration, control, and management interfaces. The dashed lines correspond to data interfaces. The dashed red lines carry tag ID bearing information and require high bandwidth and low-latency connections. Therefore, they typically reside on the same segment of a local area network.

ATR7000 Advanced Array Reader (AAR)

The ATR7000 Advanced Array Readers are EPC Gen2 readers with an integral phased array antenna capable of steering beams and estimating the bearing (angle of arrival) of EPC Gen2 tags. This product in the RFID portfolio is based on a Zebra proprietary advanced array architecture that provides unprecedented location accuracy and real time tracking of RFID tags.

A summary of the ATR7000 key product features are:

- Integral 14 element antenna array.
- Advanced multi-channel radio architecture provides accurate bearing estimations in a single read.
- Host software compatible with Zebra's family of fixed RFID readers with support for embedded and external applications.
- Integration of Zebra's proprietary ASIC-based RFID radio.
- GPIO with external power for driving actuators and sensors.
- Support for several standard mounting options to simplify installation.
- Two power options; 802.3at Power over Ethernet (PoE+) or external +24 VDC power supply.
- Environmental specifications suitable for industrial and warehouse applications (-20 C to +55 C operation and IP51 sealing).

RTLS Services

RTLS Services (CLAS) serves as a data aggregator that executes location analytics to estimate the tag location and reports out unique tag ID, location, and time-stamp in real-time.

RTLS Services performs the following primary functions:

- Discovers readers on a local network.
- Configures each reader to read tags and report the estimated bearings.
- Estimates the tag location based on the bearings reported by the reader.
- Reports the location estimates to a location endpoint.
- Provides software interfaces to middleware applications that enable end-user solutions to associate items with identity, location and movement information, and delivers business logic to streamline operations or workflows.
- Provides an interface to end-users to configure and manage the RTLS system.
- Provides interface to manage and configure the ATR7000 readers in the facility.
- Provides license management functions for RTLS and CLAS software.

The RTLS Services software consists of three major components:

- RTLS Configuration and Management Server (CNM)
- Location Analytics (LA)
- Radio Control & Data (CND)

RTLS Services is deployed as a group of Docker containers. A container is the mechanism that minimizes operating system and hardware dependencies, as well as isolates RTLS from the other software components that comprise a solution, allowing them to coexist on the same infrastructure. It is expected that RTLS Services typically resides on the same physical server as the solution.

A description of these and other components important to system operation follow below.

RTLS Configuration and Management (CNM)

As shown in Figure 1, the RTLS configuration and management server is the primary component within RTLS Services responsible for managing and configuring the system, including system start and reset, reader discovery, initial and ongoing configuration of LA and CND, firmware and software upgrades, etc. CNM is a component of RTLS Services that is resident on the server.

RTLS also provides the configuration and management interfaces (API) to the solution software through a RESTful interface, a common framework found in enterprise environments.

Location Analytics (LA)

Figure 1 also illustrates that Location Analytics (LA) is the primary component within RTLS Services responsible for aggregating bearing information received from the ATR7000 overhead readers, estimating x-y-z tag location, determining if a tag is moving (dynamic) or not moving (static), applying additional advanced algorithms that enhance static and dynamic location (tracking) accuracy, and reporting a final tag location estimate with metadata (EPC, timestamp, etc.) to a location data endpoint. LA also has the capability of combining raw bearing and location estimates from multiple RFID tags affixed to the same asset (for example. forklifts) to improve overall location accuracy and/or provide orientation and directionality information. The figure illustrates three AARs for simplicity, although, operation is designed to scale up to the maximum of 1000 readers per site. While LA is considered a components of RTLS Services, it is deployed by CNM to the readers at system start.

The interface between LA and the CND is optimized to be a high bandwidth, low latency one-way interface that carries only tag ID and bearing information, as indicated by the red arrows in the Figure 1.

Radio Control & Data (CND)

The Radio Control & Data (CND) component is a reader-based application (process) that configures, controls, and maintains a connection to the RFID radio (engine), receives tag bearing reports from the radio and passes them to LA, and ensures the timestamps on the bearing reports are synchronized to the system time source.

While CND is considered a component of RTLS Services, it is deployed by CNM to the readers at system start.

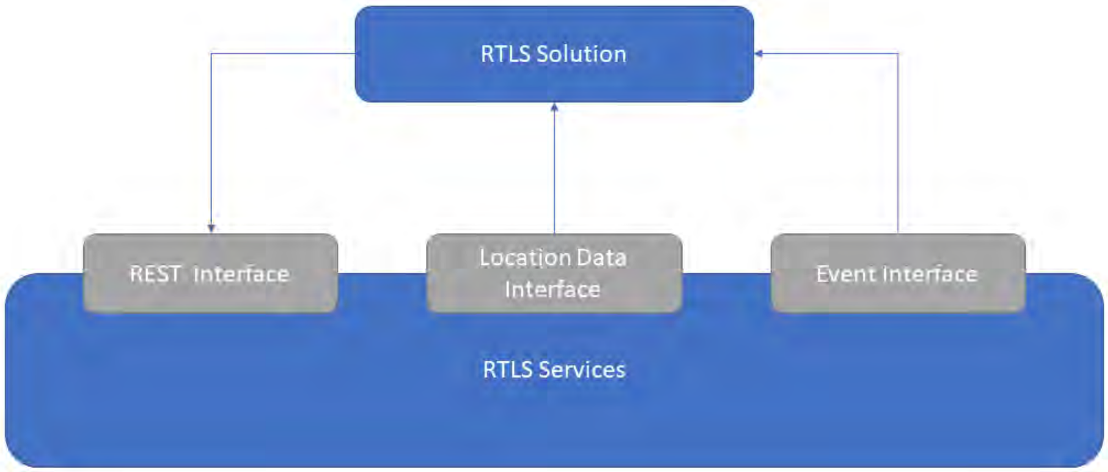
ZAATS Interfaces

ZAATS presents three main interfaces:

1. A REST based management interface.
2. A messaging stream interface for location data.
3. A messaging stream interface for health and monitoring events.

The ZAATS REST API allows applications to view, configure, manage, and monitor various system components in the RTLS system. The ZAATS location data interface allows the client application to consume the location data output by the ZAATS system. The ZAATS event interface allows the client application to consume the health and monitoring events data output by the ZAATS system.

Figure 2 Interface Overview



REST Interface

The REST Interface is the primary mechanism to configure and manage the ZAATS system. It supports the ability to query the version, status, configuration of the RTLS system; start and stop the system; and reboot the ATR7000 readers. It also supports setting user-defined filters specifying the frequency and format of reported tag data.

Location Data Interface

Location update messages are sent from the LA components within RTLS through the Location Data Interface to a Location Data Endpoint (MQTT server or a Kafka broker). The RTLS customer's middleware application can consume these location update messages from the Location Data Endpoint to transform information about asset location into solutions that enhance efficiency and workflows of end user operations.

Events Interface

Health and Configuration events notification messages are sent from CNM within RTLS through the Events Interface to a Event Endpoint (MQTT server or a Kafka broker). The RTLS customer's middleware application can consume these event notification messages from the Event Endpoint to implement solutions for monitoring of the RTLS system and raise alerts to end users about system events.

Deployment Overview

Introduction

This chapter provides an overview of the ZAATS deployment process.

Project Phases

A ZAATS deployment generally consists of seven phases, as shown in the Table 1 on page 15 below. The remaining chapters of this guide describe each of the seven phases and also provide additional guidelines on how to ensure a successful deployment.

Deployment Team Roles and Responsibilities

The following are critical roles that should be defined as early as possible in the deployment process, along with major responsibilities:

- **Program Manager**: oversees and coordinates team activities, works with the business lead, technical lead (or system designer) and end user to define high-level requirements, and set the overall project objectives.
- **System Designer / Solution Architect**: responsible for detailed requirement definition, creating the preliminary and final site map, Equipment Manifest, and bill of materials; working with the end-user to ensure appropriate selection of RFID tags for all assets to be tracked; as well as ensuring that all system performance objectives are achieved.
- **Network Designer**: responsible for designing the local area network (site-based) and backhaul, including cabling requirements, ensuring adequate switch capacity and port availability, and for assigning IP addresses to all devices.
- **Site Inspector**: responsible for observing and ensuring that the use case and workflows are accurately documented, that the facility site map is accurate, and that all facility-related factors that could impact a deployment are documented and communicated to the system designer and site survey team.
- **Site Survey Team**: responsible for ensuring that the final, pre-installation site map, including mounting locations and methods are viable; identifying all permanent landmarks to be used in the post-installation survey, and for ensuring that the logistics of a site deployment can be successfully executed according to the final site map.
- **Network and Hardware Installation Team**: responsible for the installation of all reader and network hardware and basic operational verification, post installation survey (exact reader x-y-z locations) and updating the final Equipment Manifest.
- **Software Deployment Lead**: responsible for defining the server specification and requirements, deploying the CLAS software, as well as pre-installation and post-installation validation.

- **Validation Team**: responsible for configuring the system and ensuring it is fully operational and performing as outlined in the requirements.

Table 1 Phases and Detailed Steps in a ZAATS Deployment

Project Phase	Detailed Steps
Requirement Definition	• End User Interview (or workshop) • Use Case and Requirement Definition
Preliminary System Design	• Site Inspection • Select Asset Tag Type(s) • Preliminary Site (RF Coverage) Map • Preliminary Network Design • Preliminary Equipment Manifest • Preliminary Bill of Materials (BOM)
Site Survey	• Preform Site Survey
Finalize System Design	• Update Network Design and Site Map • Update Equipment Manifest and Finalize BOM
Server and Software Installation	• Install CLAS Software
Hardware Installation	• Network Installation and Cabling • ATR7000 Reader Installation • Basic Operational Verification of Reader/Network Hardware • Survey Reader Locations • Finalize Site Map and Equipment Manifest
Post-Installation Validation	• RTLS Software Integration • System-level Operational Validation • End-User Handoff

Requirement Definition

Introduction

This chapter describes the requirement definition phase of a ZAATS deployment, covering the first steps in the deployment process.

The requirement definition phase consists of the following steps:

1. Determine the use cases, coverage areas, location accuracy, latency, and any other relevant requirements or constraints.
2. Document the existing network infrastructure (switches, cabling, availability of PoE+, WAN capacity, etc.) and determine if this will be a local (on-premise) or remote server installation.
3. Define the assets to be tracked, cost, performance, and other process-related considerations.
4. Obtain the site map for each facility.
5. Define an origin location (0,0,0) and coordinate system for the site (or multiple sites).

The above steps can generally be accomplished through an interview or workshop with the end-user or customer operations team.

Use Case Definition

The first step of any ZAATS deployment is to define the use case(s) and identify specific solution requirements. Some common applications for ZAATS are:

- Warehouses and Distribution Centers
- Cross-docks
- Manufacturing operations
- Dock doors and portals

The use case(s) will drive the coverage area and accuracy requirements, which in turn drive the RF infrastructure requirements of the ATR7000s. Equally as important as defining the coverage area and accuracy requirements is understanding the number of items in a facility to be located and tracked, the density of items, and if the RTLS system latency (approximately 2-3 seconds) supports the business process and workflow needs.

In documenting the use case(s), it is important to capture the life cycle of an RFID tagged asset, the list of actions and event steps that comprise the life cycle of the asset, and any implied location accuracy or latency requirement associated with the steps.

As an example of a use case in a distribution center (DC) or warehouse application, an RFID tagged forklift or hand truck removes an RFID tagged pallet or item from a trailer and brings it to its destination or to a staging area for

processing and later retrieval. The pallet or item must be identified, along with the timestamp and dock door it left the trailer, the forklift or hand truck that carried the item, and final location of the asset and the time it arrived. A similar use case in a cross-dock application, an RFID tagged forklift removes an RFID tagged pallet from a trailer, carries the pallet to another trailer/dock door and places the pallet into the trailer. The pallet must be identified, the time it left the trailer noted, the dock door it entered, forklift, and the trailer and dock door it was delivered to (with timestamp) are recorded.

End User Interview

Typically, the first engagement between the technical team (system designer, network designer, software lead) and end user is structured as an interview or workshop. Below is a sample checklist that can be used to guide the end-user interview.

- Description of use case(s), business process, and work flow.
- Building type and coverage environment (open space or compartmented, floor material, ceiling height and type, presence of metallic structural components or obstructions).
- Square foot coverage requirements.
- Request/obtain site map.
- Local coordinate system defined.
- Detailed description of items to be tracked; e.g. size, material composition, total items within facility, item density, stacking and/or shelving requirements, and maximum expected tag height.
- Location accuracy and tracking (latency) requirements.
- Existing network infrastructure, including PoE+ and/or electrical power.
- Identify location of server closet, rack space, and switch location.
- Local premise or remote server.
- Backhaul (WAN) requirements.

In a multi-facility deployment, any similarities and/or differences in any of the above criteria should be noted.

After the interview is complete, the technical team, including the system designer/solution architect and network designer should document the findings of the interview as well as any additional relevant technical requirements that may impact the system design and deployment.

Preliminary System Design

Introduction

This chapter describes the preliminary system design phase of a ZAATS deployment. The development of the preliminary system design based on end user requirements and use cases is one of the most important factors in achieving a successful ZAATS deployment.

The preliminary system design phase consists of the following steps:

1. Perform an (optional) initial site inspection.
2. Define server specification if a local (on-premise) server is used.
3. Determine the type(s) of RFID tags that will be required.
4. Determine the number of ATR readers required to support the coverage area and accuracy requirement and create a preliminary site map for each facility.
5. Preliminary network design (switches, cabling, power, WAN/backhaul)
6. Create a preliminary Equipment Manifest and preliminary bill of materials (BOM) for each facility.

The above steps are performed by the system designer/solution architect and other qualified technical specialists with experience in network and RF system deployments and site planning.

Initial Site Inspection

Prior to installation of a ZAATS RTLS deployment, a site inspection of the facility is strongly recommended. The objectives of the site inspection are to:

- Deepen the understanding of the use cases, items to be tracked, the facility environment, and the processes and work flows that may impact the initial design.
- Document the ceiling type and relevant mounting considerations, especially the maximum and minimum allowable heights that the ATR7000 readers will be installed. See note below.
- Ensure that the facility map is accurate and note any deviations or RF coverage obstructions.
- Identify the location of server closet and existing network infrastructure.
- Allow the site inspector to document their findings and make suggestions to the system designer or site survey team through a site inspection report.

NOTE: The mounting height of the ATR7000 readers is one of the most important physical considerations in a ZAATS deployment. In most cases, the ideal mounting height is between 15’-17’, although, may range anywhere between 12’-20’.

The following are guidelines that should assist the site inspector in creating the site inspection report:

- Walk the facility and verify that the floor plan or layout is consistent with the site map.
- Determine if the use cases, processes, and work flows are consistent with what was documented in the requirement phase, and note any deviations or other relevant observations in the site inspection report.
- Inspect all areas to be covered with ATR readers, measure the mounting height, and confirm the mounting method is appropriate for each area (it is possible or likely that one universal mounting approach may not be applicable to an entire facility).
- Note if the facility has trusses that facilitate mounting with the mounting pole accessory, or determine if a more customized mounting solution will be required.
- Document and photograph often, especially any challenges that exist and recommend a solution, if possible.
- After the site inspection, complete a site inspection report and make it available for internal review.
- If necessary, ensure the site map is updated based on your findings to better prepare the site survey team to conduct an efficient and thorough site survey.

NOTE: In a multi-site installation, it may not be required that every site be visited if the use case is identical and the facilities are similar.

Minimum Server (System) Requirements

For installations that require an on-premise server, Zebra has validated the CLAS RTLS software on several hardware platforms. Since most of the intensive location analytics processing is distributed among the ATR7000 readers, the computing requirements are relatively modest. The most important considerations, therefore, are related to fault tolerance, including hardware reliability and system availability. A server with the following components related to processing requirements are sufficient to operate the CLAS software:

- Quad Core CPU @ 2.4 GHz (or equivalent)
- 16 GB RAM
- 64 GB of free hard disk space
- Linux OS (Ubuntu 18.04 LTS and above)

For more information, please refer to the CLAS Server and Software Installation Guide (p/n MN-003197-xx).

Network and Other Hardware Requirements

All ZAATS installations require a LAN to support the ATR7000 reader population. A typical LAN consists of the following:

- Switch(es) with multi-Gbps switching bandwidth and support for 1000 MB Ethernet
- Cat5e or Cat6 cables, one for each ATR7000
- Rack for mounting
- Fan(s) for cooling
- Power source

The key component of the LAN is the switch (or switches) that comprise the switching fabric. Likely there will be several switches since most managed enterprise switches for small-to medium-scale edge deployments are available in 24-port and 48-port models. Ensure that the switch has non-blocking capacity on the order of 1Gbps

times the number of ports. Also ensure that the switch supports PoE+ (IEEE 802.3at), or alternatively, one or more midspans will be required in addition to the switch(es). It may be preferable to use a midspan, as most PoE+ switches do not have the power handling capability to provide full power to every port. Alternatively, the readers may be powered using the optional 24V external supply available from Zebra (p/n PWR-BGA24V78W1WW).

NOTE: If not powered using the 24 V external power supply, the ATR7000 readers require PoE+ and will not operate using standard PoE (IEEE 802.3af). LLDP power negotiation is also supported. The maximum power consumption per reader is 22.9 W (typical 22 W).

See Appendix: Tools and Resources for a list of recommended network hardware for use in a ZAATS deployment.

Tag Selection and Readability

Tag readability and tag read rates are two of the most important factors in achieving good location accuracy and real-time performance of the ZAATS system. Zebra has identified several tags that provide suitable performance for a variety of use cases. The Zebra ZBR4000 Tag with the NXP UCODE8 RFID IC, shown in Figure 3, has been developed specifically for the ZAATS system. It represents the latest in RFID tag performance with high RF sensitivity, good performance in all tag orientations, and exhibits excellent readability at long distances.

Dual-dipole tags available from Avery, Confidex, Smartrack, and other medium to large size standard dipole RFID tags with the NXP UCODE8 chip can also be used successfully with the ZAATS system. Table 2 on page 21 provides several examples of tags that may be considered. The exact choice will depend on several factors, including material composition of the items to be tracked, item density, reader height and density, stacking and/or shelving requirements, and cost.

Other RFID tags with single dipole designs and older, less sensitive RFID ICs can generally be read at the distances required of ZAATS, although, they may not have the multi-orientation readability desired which can result in reduced system performance.

Figure 3 Zebra ZBR4000 Tag

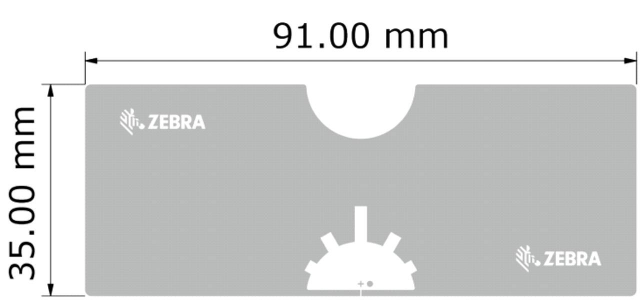


Table 2 Tag Types Use Cases

Use Case	Tag Type	Description/Comments
Packages, containers (non-metallic)	Zebra ZBR4000 Tag Most dual-dipole tags Most mid-sized or large tags using NXP UCODE8	The Zebra ZBR4000 Tag with the NXP UCODE8 chip has been thoroughly tested to work well at needed ranges and in multiple orientations.
Metal objects, packages, or containers with no intent for long-term use or durability.	Same as above applied in a “flagged” manner - see Figure 4 Printable “on-metal” label such as Zebra Silverline.	A well designed on-metal tag will use the metal surface of the object as part of the antenna structure to increase the performance of the tag.
Metal objects with permanently affixed tags (e.g. for forklifts, machinery, trolleys, metal shelving, etc).	Omni ID Dura 1500 Omni ID Exo 750 Confidex Ironside Slim Printable “on-metal’ label such as Zebra Silverline.	Metal mount tags with a specified range of greater than 25 ft are recommended.
Long Range People ID	Zebra UHF Badge Cards	

Figure 4 Examples of RFID Tags Applied in a Flagged Technique

NOTE: To ensure reliable system performance, RFID tags must exhibit “good readability”. Perform a simple yet reliable tag readability test as follows: using a hand-held reader with transmit power set to produce 30 dBm EIRP stand 25’ to 30’ away from a tagged item exactly as it will be tagged on the asset in normal operation; direct the hand-held reader toward the item and wave it slightly up and down, left and right; ensure that the tag can be reliably read. This test should be performed on a variety of items representative of all use cases. When readers are mounted higher than 17’ off the floor and assets are stationary for long periods of time, or when the highest levels of location accuracy are desired, then a 35’ read distance is recommended.

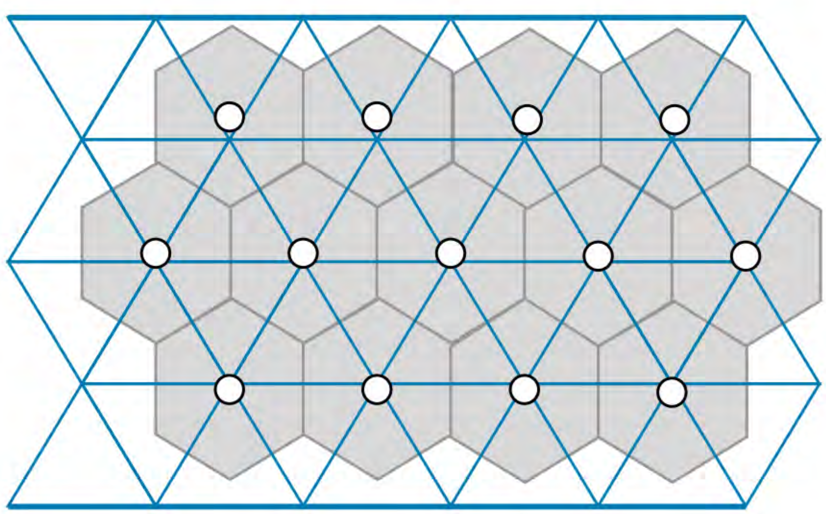
ATR7000 Coverage

The coverage area and number of readers required to reliably support an ATR7000-based ZAATS system depends on many factors. Most important is the relationship between the reader-to-reader spacing, the height at which the readers are mounted, the location accuracy requirements, and the tradeoff between cost and performance. To achieve maximum packing density and, therefore, the most cost-effective coverage, a triangular grid is employed. Using a triangular grid, the coverage zones are hexagonal and shaped like a honeycomb as illustrated in Figure 5.

Note in the figure below that the ATR7000 readers are installed at the vertices of equilateral triangles with equally spaced sides, separated by distance, s. The area per hexagonal cell is given by the equation:

$$Area_{CELL} = \sqrt{3}/2 \times s^2$$

Figure 5 Illustration of Hexagonal Coverage Areas Obtained Using Triangular Grid



The ATR7000 provides coverage over an antenna scanning angle ranging from 0º to 360º in azimuth and from 0º to ±60º in elevation, therefore, the maximum coverage area of a single ATR7000 reader occurs when the spacing, $s = 2^* r_{max} = 2 * \text{Tan}(60^o) * h$.

This maximum coverage is illustrated in Figure 6 and given by the equation:

$$Area_{MAX} = \sqrt{3}/2 * 4*\text{Tan}^2(60^o) \times h^2 = 10.4 \times h^2$$

Where h is the mounting height of the readers.

While the above equation may predict coverage, in practice where high levels of real-time performance and location accuracy are essential, two modifications to the above are required.

First, the maximum tag height must be taken into consideration:

$$h = h_{reader} - h_{tag}$$

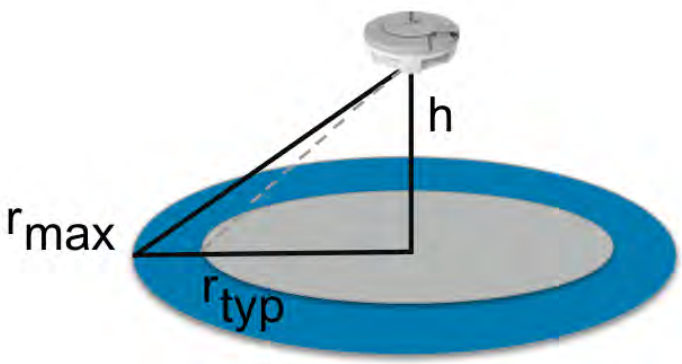
Second, a sufficient amount of overlap between ATR coverage areas is required. Although, the ATR7000 elevation scan range extends to ±60º, location accuracy is highest when the elevation scan range extends only to ±54.7º. Therefore, a more typical reader-to-reader spacing becomes:

$$s_{typ} = 2 \times r_{typ} = 2 \times \text{Tan}(54.7^o) \times (h_{reader} - h_{tag}) = 2.83 \times (h_{reader} - h_{tag})$$

and:

$$Area_{ATR} = \sqrt{3}/2 \times S_{typ}^2 = 6.93 \times (h_{reader} - h_{tag})^2$$

Figure 6 Maximum Coverage Area and Typical Coverage Area of ATR7000



NOTE: ZAATS supports "multi-tagged" items, where two or more tags are placed on the same item with a fixed, known geometry. In this case, the tag height used can be the average (not maximum) tag height of all tags affixed to the same item. For more information on "multi-tagged" items, see ZAATS Tag Data and Numbering Guide, (p/n MN-003199-01).

Using the above formula guarantees coverage overlap between ATR readers in adjacent cells and provides maximum coverage area per reader. However, for applications that require the highest levels of location accuracy, the reader-to-reader spacing should be reduced by up to 15% (which increases the number of ATR readers by ~30%):

Therefore:

$$s_{max\_accuracy} = 0.85 \times 2.83 \times (h_{reader} - h_{tag}) = 2.40 \times (h_{reader} - h_{tag})$$

$$Area_{ATR\_max\_accuracy} = \sqrt{3}/2 \times s_{max\_accuracy}^2 = 5.00 \times (h_{reader} - h_{tag})^2$$

As an example, in an installation with readers mounted at a height of 15' off the floor and tags mounted 3' off the floor, the nominal reader-to-reader spacing is 34' and the coverage area per reader is 1000 square-feet. For the highest levels of location accuracy, the reader-to-reader spacing is reduced 15% to 28.8' and the coverage area per reader is 720 square-feet. To achieve 1000 square-feet coverage, the reader-to-reader spacing must be 34', however, to obtain the additional cell overlap required for the highest levels of performance, the mounting height of the reader would be increased to 17.1'. In all cases, it is important to ensure that the RFID tags exhibit "good readability" to achieve reliable accuracy and real time performance (see the previous section Tag Selection and Readability). It is worth noting that $Area_{MAX}$ is approximately 3000 square-feet when ATR readers are mounted at 17.1'. This 3-to-1 ratio between $Area_{MAX}$ and $Area_{ATR}$ is an important factor of how the ZAATS system achieves its high levels of performance.

One final point concerning the selection of reader-to-reader spacing (grid size) is that the structural aspects of the site must also be considered. The basic structural components of most facilities are the support columns and roof trusses. It is often possible to choose the grid spacing such that a grid can be maintained without interfering with

the building structure. It is especially important to ensure readers are not installed within 6' of a support column (see additional guidelines below).

NOTE: The preceding material on coverage and best practices has focused on wide area coverage where readers provide overlapping coverage. Another common coverage scenario is warehouses with pallet racks where ATR readers are mounted in a linear fashion down the center of each drive lane. To ensure adequate coverage line of site is required within the cone formed by a 45^{o} angle emanating from each ATR reader for all but the top shelf (see Figure 7); i.e., the reader-to-reader spacing down the center of the aisle should be twice the difference between the mounting height of the reader and the height of the bottom of the top shelf. The RTLS system will track the item up and down the racks and send tag reports with x-y-z locations until the item is raised to a maximum height where the tag report then indicates that the item elevation is out of range. The solution software must then infer the item is on the shelf above the location it was last observed.

Figure 7 Warehouse Deployment Scenario with Pallet Racks

Creating the Preliminary Site Map and Equipment Manifest

The next step in the preliminary system design is to specify the installation locations (i.e., x-y-z coordinates) of the ATR readers and create the preliminary site map. In a multi-facility installation, this should be done for each facility. The steps to complete this process are outlined below.

1. Highlight the coverage zones on the site map (for each facility) and note local coordinate system origin and any known reference locations.

2. Based on the use case(s), determine the tag height (h_{tag}).
3. Based on the facility mounting or structural constraints and tradeoff between coverage per reader (cost) and accuracy, determine the ATR mounting height (h_{reader}), reader-to-reader spacing (s), and coverage area per ATR reader.
4. Using the guidelines below, locate the readers on the site map adhering as closely as possible to the pre-determined reader-to-reader spacing (s), such that all zones have the desired coverage.
5. Create the preliminary Equipment Manifest with the preliminary (target) x-y-z locations of the ATR7000 readers.

The following are guidelines that should assist the system designer in creating the system design and reader locations (site map):

- The mounting height should be as close to 15'-17' as possible, although, may range anywhere between 12'-20' as explained in the previous section.
- The triangular grid layout should be adhered to as closely as possible. When deviations from a strict triangular grid are required, which will typically be the case, the system designer should minimize such deviations and do so in a way not to create coverage holes. To prevent coverage holes, ensure that reader-to-reader spacings do not exceed the target by more than 10%.
- Readers should be spaced at least 6' away from structural columns, walls, or zone boundaries, and up to a maximum of s/3 (ideally somewhere between these two limits, depending on other environmental constraints).
- Readers should be placed at least 3' away (and preferably more) from any metal obstruction; e.g. roof trusses, fans, ventilation ductwork, etc. The exception to this constraint is if the reader is mounted below the obstruction by at least 6". In this case, the constraint can be relaxed to 1'.
- Readers should not be placed near objects that would interfere with line-of-sight coverage to the items to be tracked within a coverage zone. Although, this requirement may be challenging to strictly meet in practice due to the presence of structural support columns, machinery, and other environmental factors.
- Generally, the actual x-y mounting location of any reader can deviate up to 1.5', and the z mounting location (height) of any reader can deviate up to ±0.75' (higher is better) with minimal impact to performance.

Mounting Considerations

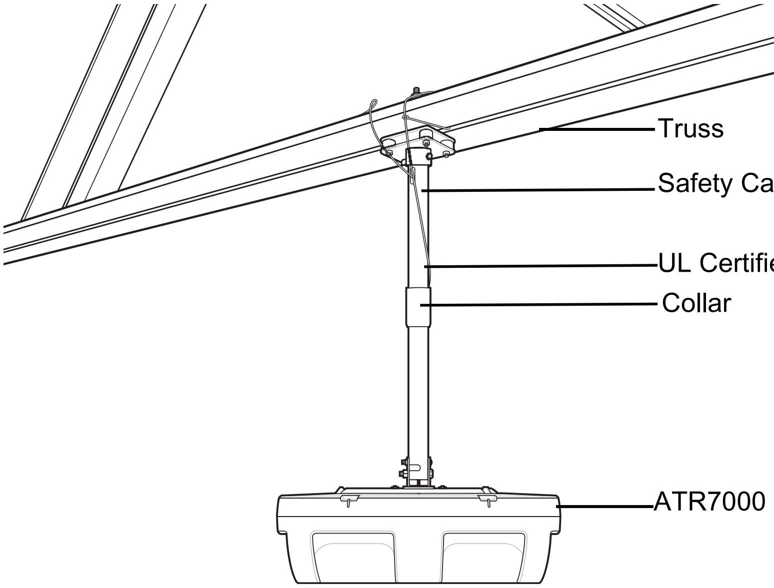
As described in previous sections, the mounting height of the ATR7000 readers is one of the most important physical considerations in a ZAATS deployment, as it directly impacts the reader-to-reader spacing, number of readers, and cost required to cover a given area.

There are three options for mounting the ATR7000 readers to the roof trusses using the accessory mounting poles:

- Installing directly to a truss - see Figure 8 below
- Installing using a strut channel clamped to the bottom of the truss.
- Installing using a strut channel and threaded rods clamped to the top of the truss.

When mounting to a truss is not feasible, the system designer will need to define a mounting method using the optional ATR7000 VESA bracket accessory (Zebra p/n BRKT-VMATR7-00).

Figure 8 Installing Directly to a Truss



NOTE: The z-axis reference that establishes the mounting height of the ATR7000 is the ground plane of the antenna array. This reference is located 4.2” (0.35’) above the bottom of the antenna radome at the seam that joins the radome and top cover. This same z-axis reference point is 2.9” (0.24’) below the connection point where the mounting bracket attaches to the ATR7000.

In selecting the mounting accessories and hardware, the system designer must take into consideration the height of the structure the readers are attached to. The site survey team will ensure during the site survey that the method chosen is suitable for the type of structure and applicable building constraints.

Zebra offers UL certified telescoping poles available in three sizes to accommodate a variety of environments, as shown in Table 3 below.

As an example, if a reader is intended to be installed at a height of 15’, the bottom of the radome is 14.65’ above the floor and the connection point to the mounting pole or VESA bracket accessory is 15.24’ above the floor. Using the BR-000237-01 at its minimum extension the truss will be 16.74’ above the floor; using the BR-000237-03 at its maximum extension the truss will be 26.74’ above the floor.

Table 3 Certified Telescoping Poles

Zebra Part Number	Description	Adjustment Range
BR-000237-01	Bracket, Telescoping, Adjustable, 18”-32”, Ceiling Mount, VESA, White	1’6” to 2’8”
BR-000237-02	Bracket, Telescoping, Adjustable, 36”-66”, Ceiling Mount, VESA, White	3’ to 5’6”
BR-000237-03	Bracket, Telescoping, Adjustable, 72”-138”, Ceiling Mount, VESA, White	6’ to 11’6”
BR-000238-01	Bracket, Telescoping, Adjustable, 18”-32”, Ceiling Mount, VESA, Black	1’6” to 2’8”
BR-000238-02	Bracket, Telescoping, Adjustable, 36”-66”, Ceiling Mount, VESA, Black	3’ to 5’6”
BR-000238-03	Bracket, Telescoping, Adjustable, 72”-138”, Ceiling Mount, VESA, Black	6’ to 11’6”

In summary, a variety of mounting heights and approaches can be accommodated using the various mounting options, choice of mounting poles, and VESA bracket accessory (Zebra p/n = BRKT-VMATR7-00). More information on mounting the ATR7000 readers can be found in the ATR7000 Advanced Array Reader Integration Guide, (p/n MN-003191-xx)

Equipment Manifest

The Equipment Manifest is a repository of information that captures all attributes required for system installation, configuration, and operation in a single location. The Equipment Manifest is used by the system designer, survey team, network installers, installation team, and validation team to identify all materials needed for a ZAATS installation, and is also used to create the configuration files required during the server and software installation process.

At the preliminary design phase, the Equipment Manifest will include the ATR friendly names and preliminary x-y-z reader locations. The serial number, MAC address, x-y-z locations, and reader orientations (ϕ) will be finalized at installation. Network related information, for example IP address, should be provided to the system designer by the network designer by the network designer and/or end user IT department when available, but prior to system installation.

A sample Equipment manifest is shown in Table 4 below.

Table 4 Sample ZAATS Equipment Manifest: ATR7000 Tab

Friendly Name	Hostname	ATR S/N	MAC Address	IP Address	X-loc	Y-loc	Z-loc	ϕ	Midspan/Switch Port
ATR01					40.0	100	17.1		
ATR02					15.0	87.5	17.1		
ATR03					40.0	75.0	17.1		
ATR04					15.0	62.5	17.1		
ATR05					40.0	50.0	17.1		
ATR06					15.0	37.5	17.1		
ATR07					40.0	25.0	17.1		

Completing the Preliminary System Design

Below is a sample checklist of exit criteria that can be used for the preliminary system design phase:

- Preliminary network design, including reader power sources, detailed server specification (if required), number and type of switches, midspans, and cabling requirements.
- Preliminary RFID tag specification(s).
- Preliminary site map showing the local coordinate system origin, reader locations (x-y) and mounting height (z), structural features, and other known obstructions or objects that can impair RF coverage.
- Preliminary Equipment Manifest.
- Preliminary comprehensive bill of materials (BOM).
- Preliminary system design document (report) summarizing the above, to be used as a guide for the site survey and installation teams.

Site Survey

Introduction

This chapter provides information for the survey team in performing an in-depth comparison of the preliminary site map to the respective on-site ZAATS component locations to ensure the map has been developed according to best practices for ZAATS hardware installations. The survey team also updates the map, where required, for component locations that are inconsistent with best practices.

The objectives of the site survey are to:

- Ensure that the system will deliver the required wireless coverage and location accuracy.
- Determine the presence or absence of existing network infrastructure, the data capacity of the existing network, and identify the location of the server closet or mounting location of the switches.
- Validate the local coordinate system and identify permanent reference location points (landmarks).
- Validate that the preliminary site map is accurate, note any deviations or obstructions, and modify the site map (i.e. reader locations) accordingly.
- Validate that the reader mounting height is practical for each location and modify the site map (i.e. reader locations) accordingly.
- Ensure that the planned mounting scheme for each reader location is suitable for the type of structure and applicable building constraints, and to document alternative solutions, if needed.
- Ensure that electrical power is available, either through PoE+ enabled switches or midspans, or by electrical outlets in near proximity to where the readers will be located.
- Define all materials and tools that will be required by the installation team.
- Develop the site survey report, documenting any challenges that exist or special instructions that need to be considered by the installation team, and to make the report available for internal review.

Guidelines for Performing the Site Survey

The following are guidelines that should assist the site survey team in performing the site survey and creating the site survey report:

- Become familiar with the facility map and site map and review all ATR locations.
- Identify the facility landmark that will serve as the (0,0,0) origin for the local coordinate system and identify the permanent reference location points (landmarks). Identify enough landmarks such that every landmark has at least two other visible landmarks within 200’.
- Locate each ATR on the site map and ensure that each ATR location is visible to at least two landmarks.

- Place yourself in an appropriate viewing location to determine if any obstructions or other factors will impede the proper installation of the ATR in its planned location.
- Measure from the floor to the lower surface of the structure to determine if the mounting height specified on the site map is feasible. If the lower surface of the mounting structure is not high enough, then the site survey lead will need to discuss an alternate approach with the system designer and modify the site map accordingly.
- If a planned ATR location or mounting height is unsuitable due to an obstruction or mounting at the specified height is not practical, it is acceptable to move the location in any direction up to 18” or change the mounting height up to 9”. Take photos of the original location and new location, and indicate the reason necessitating a move. For consistency, take all photos facing the rear of the facility (if possible) and angled back to view the ceiling.
- If a minor location or height change is not practical, then the survey team needs to be prepared to modify the preliminary site map in a manner that maintains the coverage objectives. Typically, this is either by tolerating a minor sacrifice in coverage, or by replacing a single ATR reader with two ATR readers (at different locations). It is advised to contact the system designer or technical lead in these situations.
- If a planned location requires any deviation, the site map must be modified to reflect the revised location. Ensure a person familiar with the best practices for ATR locations updates the map.
- Ensure that the planned mounting scheme for each reader at each location is suitable for the type of structure and applicable building constraints, and to document alternative solutions (for later review by the system designer) if necessary.
- Validate the presence or absence of existing network infrastructure and network capacity, including the location of the server closet or mounting location of the switches.
- Ensure that the electrical power is available, either through PoE+ enabled switches or midspans, or by electrical outlets in near proximity to where the readers will be located.
- Define all materials and tools that will be required by the installation team.
- Document and photograph any challenges that exist and provide instructions to the installation team in the site survey report.
- After the site inspection is complete, prepare a site survey report and make it available for internal review.

Completing the Final System Design

Introduction

This chapter describes the final system design phase of a ZAATS deployment, the last step prior to the arrival of the installation team.

The final system design phase consists of the following steps:

1. Review the site survey report.
2. Finalize the Site Map with exact installation locations of the ATR7000 readers and network hardware.
3. Finalize the network hardware and network design, including assignment of IP addresses if not using DHCP.
4. Update the Equipment Manifest and the final bill of materials (BOM).
5. Prepare the final system design and site report.

After the site survey, working with the site survey lead and network designer, the system designer will finalize the site map and create detailed installation notes and instructions to guide the network and hardware installation team.

Finalizing the Pre-Installation Site Map, Equipment Manifest, and Bill of Materials (BOM)

It is quite often the case that the site survey team needed to make modifications to the preliminary site map based on mounting considerations, ceiling height, building, or other structural constraints. General guidelines were provided in the previous section where it is acceptable for the site survey team to move the preliminary x-y location of a reader in any direction up to 18” or change the mounting height up to 9”. It is very important that these locations are now considered final, and that no significant deviations to mounting height or x-y location be made by the hardware installation team after finalization of the site map. However, from a practical perspective, it is important that the system designer consider that the hardware installation team may still need to make minor adjustments, up to 6” in height or location, based on each unique mounting situation.

After updating the pre-installation site map, the Equipment Manifest should also be updated with any adjustments to reader quantities, installation locations, and assigned IP addresses (See Table 5) and the bill of materials (BOM) updated with the final reader count, mounting hardware, network hardware, or other hardware required for installation. Comparing the pre-installation manifest in Table 4 to the preliminary manifest in Table 5, note that the y-locations of the ATR readers were adjusted by 15.0’.

Table 5 Sample Pre-Installation ZAATS Equipment Manifest

Friendly Name	Hostname	ATR S/N	MAC Address	IP Address	X-loc	Y-loc	Z-loc	ϕ	Midspan/Switch Port
ATR01				192.168.7.201	40.0	115.0	17.1		
ATR02				192.168.7.202	15.0	102.5	17.1		
ATR03				192.168.7.203	40.0	90.0	17.1		
ATR04				192.168.7.204	15.0	77.5	17.1		
ATR05				192.168.7.205	40.0	65.0	17.1		
ATR06				192.168.7.206	15.0	52.5	17.1		
ATR07				192.168.7.207	40.0	40.0	17.1		

Below is a sample checklist of exit criteria that can be used for the final system design phase:

- Final network design, including reader power sources, detailed server specification (if required), number and type of switches, and cabling requirements.
- Final RFID tag specification(s).
- Updated, pre-installation site map showing the local coordinate system origin, reader locations (x-y) and mounting height (z), structural features, permanent landmarks, and known obstructions or objects than can impair RF coverage.
- Updated, pre-installation Equipment Manifest.
- Final comprehensive bill of materials (BOM).
- Final system design and site report with mounting and installation instructions to be used as a guide for the network and hardware installation team.

Installation of CLAS Server Software

Introduction

In cases where a local on-premise server is used, the CLAS software should be installed and pre-validated on the on-premise server and should be shipped to the end-user facility prior to the arrival of the installation team.

For more information, see CLAS Server and Software Installation Guide (p/n MN-003197-xx).

Installation of ZAATS Reader and Network Hardware

Introduction

This chapter describes the hardware installation phase of a ZAATS deployment, including the detailed steps involved in reader and network installation, and how to ensure the hardware is fully functional.

The hardware installation phase consists of the following steps:

1. Install all network hardware and Cat5e/Cat6 cabling.
2. Install electrical power to each reader location (if PoE+ is not available).
3. Configure switch(es), midspan(s), and router(s).
4. Install all ATR7000 readers.
5. Assign an IP address to each ATR7000 (if DHCP is not used).
6. Perform basic reader “health test”, including network connectivity and antenna operation.
7. Measure installed ATR7000 locations with Leica 3D DISTO^{TM}, or equivalent.
8. Finalize site map and Equipment Manifest.

Prior to Arrival of Installation Team

After completing the final system design, all materials defined in the bill of materials (BOM) need to be on-site and accessible prior to the arrival of the network and hardware installation team. In addition, all specialized equipment and tools required for mounting readers, cabling, and installing network hardware will need to be delivered or carried on-site by the team. See Appendix: Tools and Resources for a listing of some helpful resources that can facilitate installation and aid in the deployment of a ZAATS system.

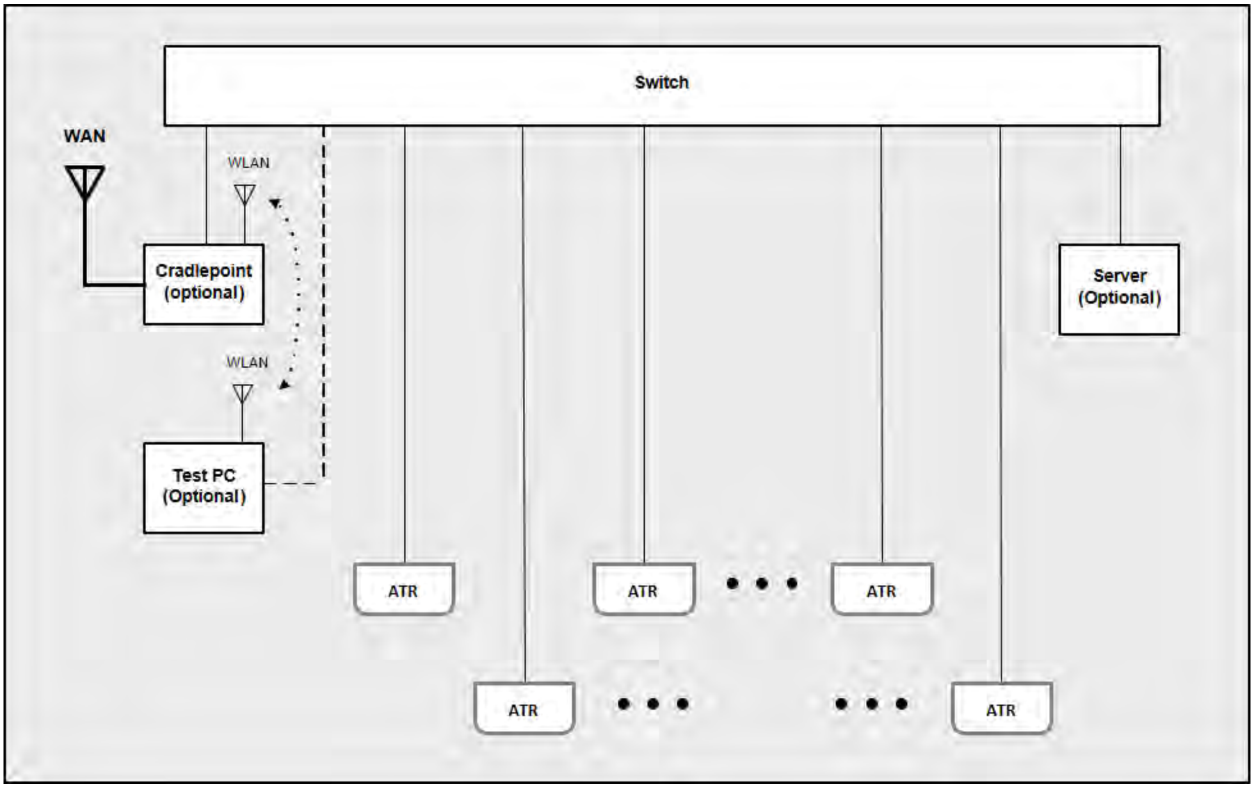
Network Installation and Cabling

The first step in deploying hardware is to install all network components in their permanent locations and all Cat5e/Cat6 cabling should be pre-wired and labeled with termination points at each reader location. It is recommended to allow a 4’-6’ service loop to facilitate minor adjustments to reader x-y-z location, if needed. If PoE+ is not available and electrical power is required, power outlets should be installed by a qualified electrician, preferably within 6’ of the final reader location.

After the Cat5e/Cat6 cables are installed they should be terminated at the switch (or midspan) and the port number should be recorded in the Equipment Manifest corresponding to each ATR reader location.

A block diagram of a typical system installation is shown in Figure 9**,** which also illustrates the use of an optional WAN router and optional test PC.

Figure 9 System Design



The following are guidelines that should assist the network engineer/specialist to ensure proper operation of the system after its installation:

- Preferably use a dedicated switch with Gpbs switching capacity for connecting all ATR7000 readers and server. This will ensure that the high network bandwidth required by the ATR7000 readers and RTLS software does not impact other devices on the network.
- Ensure IP multi-casting and IP multi-cast routing is enabled in the switch configuration. This will allow ATR7000 readers to be discoverable over the network during installation.
- Ensure that a DHCP server is available. Even if static IP addresses are used, the installation process requires DHCP.
- If using the optional WAN router, enable the bridging function to connect the two LANs, This will allow a roaming laptop (test PC) to access an ATR on the LAN through a local WLAN established by the router.

NOTE: It may be preferable to go through the installation process with the ATR/switch local network not connected to the end-user (corporate) network. This ensures no conflicts with the corporate network prior to provisioning by the end user IT department.

WAN Router Setup (Optional)

The use of a cellular WAN router on either a temporary or permanent basis is useful to provide remote access to authorized personnel to the ZAATS system. Also, during installation, a router with WLAN capability can be used to establish a temporary WLAN to facilitate ATR “health testing” (See Preliminary Validation of the ATR7000 Readers).

When using the optional WAN router, the following is recommended.

- Ensure that the router is assigned a static IP address. This will allow direct remote access to specific ports and services of systems running on the local network.
- Port forwarding needs to be enabled. The following ports will need to be forwarded to the local network address of the RTLS server.
    - SSH: Port 22 (TCP)
    - HTTP: Port 80 (TCP)
    - HTTPS: Port 443 (TCP)
- If using an optional Windows test PC (see below):
    - RDP: Port 3389 (TCP & UDP)

NOTE: To maintain http, https, and SSH access to both the WAN router and the RTLS server, the ports for these services must be modified for the router.

Figure 10 shows the typical port forwarding requirements for both a local RTLS server and an optional Windows test PC. IP address 192.168.7.199 represents the RTLS server system and 192.168.7.200 represents the Windows test PC.

Figure 10 Port Forwarding Requirements for Optional WAN Router

Windows Test PC (Optional)

The use of a small Windows PC on either a temporary or permanent basis is useful for preliminary testing of the ATR7000 readers (e.g. testing with PowerSession software), post installation validation and/or remote network monitoring. The optional test PC can be accessed remotely via the remote desktop service on Port 3389, which will need to be enabled through the firewall of the local network.

NOTE: Port 3389 is a commonly restricted port on many corporate networks, therefore, an alternate approach may be required. One example of an alternate approach is to use TeamViewer software (license required) as it does not require inbound port forwarding.

Installing the ATR7000 Readers

After all network components are in their permanent locations, cable drops have been installed, and electrical power is available at each location, the process of installing reader hardware can begin. All information on

unpacking and installing the ATR7000 readers can be found in the ATR7000 Advanced Array Reader Integration Guide (p/n MN-003191-xx) and is not repeated in this document.

The following are guidelines that should assist the installation team in performing the installation:

- Ensure that all Cat5e/Cat6 cables are terminated at the switch (or midspan) prior to installing readers.
- If a PoE+ enabled switch with LLDP power negotiation is used, ensure that the ATR7000 Power Negotiation configuration setting is enabled. Setting this parameter is explained in the ATR7000 Advanced Array Reader Integration Guide, MN-003191-xx.
- Locate each ATR on the site map and ensure that each ATR location is visible to at least two landmarks.
- Install the mounting hardware, including mounting poles or brackets, at each ATR location. It is important to follow the site map as closely as possible, however, deviations in location (x-y) up to 12” or height (z) up to 6” are allowable if necessary.
- Attach and secure the ATR reader to the mounting bracket and ensure the unit is level to within 5º.
- After the ATR reader is mounted, note the orientation of the reader relative to the reference coordinate system. This is explained in Measure Location and Orientation of the ATR7000 Readers on page 38.
- Connect the reader to the Cat5e/Cat6 cable. If not using PoE+, connect the power supply connector. Validate the proper boot up sequence. When complete, the LED indicator should be solid green.
- Follow the steps outlined in the section below, Preliminary Validation of the ATR7000 Readers.
- Optionally follow the steps outlined in Basic Operational Verification (Optional) on page 37.
- Repeat for each ATR reader throughout the facility.
- Update the Equipment Manifest with the MAC address, serial number, hostname, and orientation of each ATR reader (associated with the friendly name and location coordinates).

Preliminary Validation of the ATR7000 Readers

Once the reader is installed, connected to the network and power, and the boot-up sequence has been validated, the indicator LED should be lit solid green. At this point the IP address (if required by the end-user IT department) and a basic functional health check should be performed on the reader using the installation software tools as follows:

- The installer should have a laptop (test PC) with PowerSession installed to facilitate testing immediately after mounting the reader.
- Ensure DHCP is enabled on the local network.
- If a static IP address is required by the end-user IT department:
  - Connect to the reader using the hostname and assign a static IP address assigned to the ATR (per the Equipment Manifest). This procedure is described in the ATR7000 Advanced Array Reader Integration Guide (p/n MN-003191-xx).
  - Follow the prompts to first apply changes and then re-boot the reader from within the web console interface for the network configuration changes to take effect.
- Place a tag board directly underneath the reader within 6-10’ of the bottom of the antenna radome. See Appendix: RFID Tag Board for ATR7000 Installation and Validation for details on constructing a tag board.

- Using the PowerSession RFID Demo Application with beams 400-413 enabled (these beams correspond to individual antenna elements), verify that all elements (beams) are reporting tag reads:
  - Connect to the reader being tested using the hostname (or IP address).
  - On the Settings tab, enter a custom antenna sequence of “400-413” at 36 dBm EIRP and click apply.
  - On the Main tab, click Start to begin reading.
  - Confirm that each individual antenna element from 400-413 (14 elements total) are all able to read tags with the tag board positioned directly underneath the reader within 6-10’ of the bottom of the antenna radome. This will ensure that all 14 antenna elements are functional.
- Using the PowerSession RFID Demo Application with beam 397 enabled (this beam corresponds to a 0 º elevation, or boresight beam with left hand circular polarization), verify nominal read performance is achieved by ensuring that 100% of the tags are read at an output power 6 dB less than maximum (EIRP), and that greater than 50% of the tags at an output power 12 dB less than maximum (EIRP):
  - Connect to the reader being tested using the hostname (or IP address).
  - On the Settings tab, enter a custom antenna sequence of “397” at 30 dBm EIRP and click apply.
  - On the Main tab, click Start to begin reading.
  - Confirm that 100% of the tags are read with the tag board positioned directly underneath the reader within 8-12’ of the bottom of the antenna radome.
  - On the Settings tab, enter a custom antenna sequence of “397” at 24 dBm EIRP and click apply.
  - On the Main tab, click Start to begin reading.
  - Confirm that greater than 50% of the tags are read with the tag board positioned directly underneath the reader within 8-12’ of the bottom of the antenna radome.

Basic Operational Verification (Optional)

While not strictly necessary, basic operational verification of the ATR7000 systems can be performed two systems at a time for a given row of ATR7000 readers along the North-South axis, or for a row of readers along the West-East axis, whichever is most suitable for the given installation. This verification accomplishes the following:

- Confirms that each ATR7000 reader can read RFID tags at the distances it will be required to read during normal operation.
- Confirms that each ATR7000 reader can read tags in the direction corresponding to a given beam.
- Confirms that each ATR7000 reader’s physical orientation has not been mistakenly reversed or badly misaligned.
- Confirms that there are no internal antenna faults within the reader being tested.

The basic operational test procedure is as follows:

- Place the tag board approximately three feet off the ground at a point midway between two readers on a North-South axis.
  - Connect to the “South” reader using PowerSession and apply custom antenna sequence “325” at 36 dBm EIRP. This is a left hand circular polarized beam points North (0° azimuth) at an elevation angle of 45°.
  - Confirm that greater than 50% of tags are read.
  - Connect to the “North” reader using PowerSession and apply custom antenna sequence “337” at 36 dBm EIRP. This beam points South (180° azimuth) at an elevation angle of 45°.
  - Confirm that greater than 50% of the tags are read.

- Repeat the above for all readers to ensure proper North-South beam steering,
- Place the tag board approximately three feet off the ground at a point midway between two readers on an East-West axis,
  - Connect to the “West” reader using PowerSession and apply custom antenna sequence “331” at 36 dBm EIRP. This beam points East (90° azimuth) at an elevation angle of 45°.
  - Confirm that greater than 50% of the tags are read.
  - Connect to the “East” reader using PowerSession and apply custom antenna sequence “343” at 36 dBm EIRP. This beam points West (270° azimuth) at an elevation angle of 45°.
  - Confirm that greater than 50% of the tags are read.
- Repeat the above for all readers to ensure proper East-West beam steering.

Note that due to multi-path propagation effects, a given system might not be able to read the tag board if the tag board’s location happens to fall into a null on the specific static test beam and polarization being used. It is permissible to move the tag board around slightly during testing within a 2-foot radius to confirm tag read performance. As a best practice, try first moving the tag board further away from the reader under test for a higher confidence result.

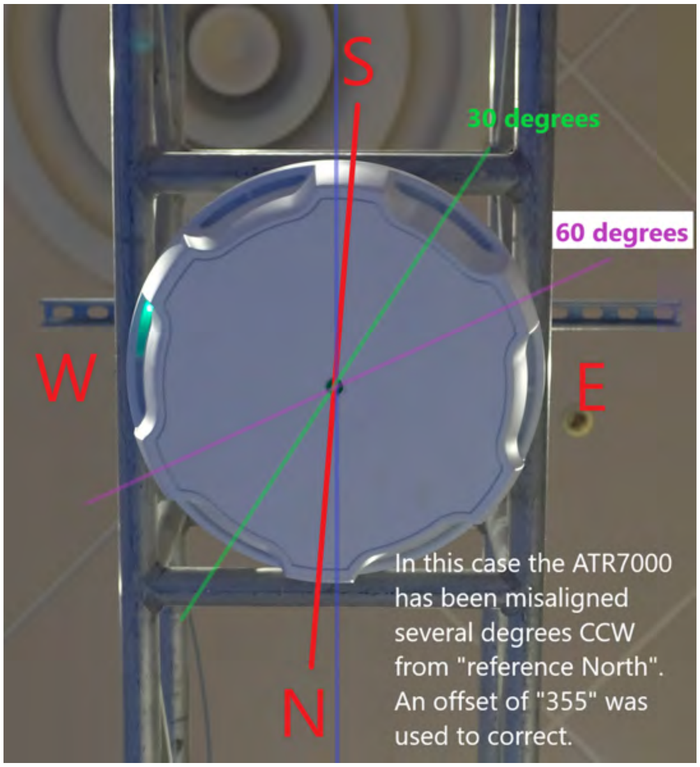
Measure Location and Orientation of the ATR7000 Readers

To achieve the full location accuracy performance potential of ZAATS, it is necessary to accurately survey the precise positions of the installed ATR7000 readers in the x, y, and z-axis with a surveying tool such as the Leica 3D Disto system. Manual measurements with hand-held laser rangefinder tools are not recommended as they will result in too much variability and have a direct negative impact on overall system accuracy.

There are two ways to survey the ATR7000 systems, directly underneath or from the side of the systems. A procedure for both methods is described in detail in Appendix: Leica 3D Instructions for ATR7000.

The ZAATS system requires that the reference reader orientation φ=0 be in the direction of the positive y-axis. The positive y-axis is commonly referred to as **facility north**, which is usually not the same north as defined by a compass reading. It is recommended, but not required, that the orientation of each reader be the same. The reader should be laser aligned as closely as possible to adjacent systems within a given row, or to a facility reference point. Any dependencies should be noted in the Equipment Manifest, as described below. When installing ATR7000 readers into a facility, it is often not possible to ensure that the orientation of every reader is aligned to the facility north. An example of a slightly misaligned reader is shown below in Figure 11 on page 39. Note in the figure, the view is from the perspective of someone standing directly beneath the reader, facing the facility north, looking straight up. Note the indentions and bulges that define the reader orientation points of 0, 60, 120, 180, and 240 degrees. Also note the green light at approximately 230 degrees azimuth. In this example the reader is oriented slightly west by 5 degrees. The orientation of this reader should be entered as 355 into the Equipment Manifest.

Figure 11 Example of a Slightly Misaligned ATR7000 Reader



Finalizing the Site Map and Equipment Manifest

The last step of the hardware installation process is to update the Equipment Manifest with the final (surveyed) x-y-z locations of the ATR readers, and to ensure that all the other fields in the Equipment Manifest have been properly recorded.

The finalized Equipment Manifest becomes the basis for configuring the RTLS Services software, as described in the following chapter. An example of a completed Equipment Manifest is shown in the table below.

Table 6 Sample Finalized ZAATS Equipment Manifest

Friendly Name	Hostname	ATR S/N	MAC Address	IP Address	X-loc	Y-loc	Z-loc	ϕ	Midspan/ Switch Port
ATR01	ATR7000F422C8		84248DF42 2C8	192.168.7.201	40.0	100	17.1	0	7
ATR02	ATR7000F476E1		84248DF47 6E1	192.168.7.202	15.0	87.5	17.1	355	1
ATR03	ATR7000F3F489		84248DF3F 489	192.168.7.203	40.0	75.0	17.1	0	11
ATR04	ATR7000F3F316		84248DF3F 316	192.168.7.204	15.0	62.5	17.1	0	3
ATR05	ATR7000F3F4A1		84248DF3F 4A1	192.168.7.205	40.0	50.0	17.1	10	13

Friendly Name	Hostname	ATR S/N	MAC Address	IP Address	X-loc	Y-loc	Z-loc	ϕ	Midspan/ Switch Port
ATR06	ATR7000F36F4B		84248DF36 F4B	192.168.7.206	15.0	37.5	17.1	0	5
ATR07	ATR7000F3F4B1		84248DF3F 4B1	192.168.7.207	40.0	25.0	17.1	0	15

Post-Installation ZAATS Validation

Introduction

This chapter describes the post installation ZAATS validation phase of a ZAATS deployment and how to ensure the system is fully functional and ready for handover to an end user.

The objectives of the post-installation validation are to:

- Ensure that the CLAS RTLS software is operational and properly configured.
- Ensure that ZAATS can locate non-moving (static) tags throughout the coverage area with the accuracy objective specified during the requirement definition phase.
- Ensure that the ZAATS system can locate moving (dynamic) tags throughout the coverage area with the accuracy and latency objectives specified during the requirement definition phase.
- Place an adequate number of “reference tags” within the coverage area to facilitate ongoing system health monitoring or troubleshooting.
- Prepare and deliver the system validation and test report to the customer or end user.

Entry Criteria

Prior to validation of the ZAATS system, the following entry criteria are presumed to be satisfied:

- All ATR7000 readers and network hardware have been installed and validated as described in the Basic Operational Verification (Optional) section of the previous chapter.
- The Equipment Manifest has been finalized with all reader locations recorded as described in the Finalizing the Site Map and Equipment Manifest section of the previous chapter.
- The CLAS/RTLS Services software has been installed, deployed, and validated as described in the Validating an CLAS/RTLS Services Installation chapter of the CLAS Server and Software Installation Guide (p/n MN-003197-xx). This includes starting CLAS with the bundled Kafka broker and verifying that the bundled Kafka consumer can consume tag ID and location data using the RTLS simulator.

RTLS Integration

After the ATR7000 has been installed and basic hardware and network operation has been validated, and after the CLAS (RTLS Services) software has been installed on the server, the next step is to integrate these two major components of the ZAATS system. This ensures that the RFID readers are reading and estimating tag bearings and that the tag reports from the readers are being ingested by the RTLS location analytics, and the resulting tag ID and location information is being directed to a live bundled Kafka location endpoint.

The following are basic steps to integrate the ATR readers and CLAS (RTLS Services) software:

1. Using the information contained in the Equipment Manifest, update the aar_info.csv file with the ATR host names, IP addresses, x-y-z locations, and orientations.
2. Ensure that radio_c_and_d_config parameter in the rtls/config/rtls.conf file is set to bearing. This will inform RTLS Services (software) that it will be operating in live mode.
3. Ensure that there are at least 10-20 RFID tags within the coverage zone, preferably located such that they are within range of several ATR readers.
4. Start RTLS Services with the bundled Kafka broker and the bundled NTP server. To do this, cd to the rtls folder and run:

```
./rtls.sh -nk start
```

NOTE: If the host is already running an NTP service then remove the “n” option from the command above.

To verify that the RTLS is indeed reporting tag IDs and location estimates on the live bundled Kafka location endpoint, follow the steps below:

5. List the Kafka topics that are created on the broker using the following command:

```
docker exec -it rtls_bitnami_kafka_container kafka-topics.sh --list -- bootstrap-server

<kafka_broker_ip>:<port>
```

6. A topic with the name “rtls.tag_location_update.v2.json” should be listed as a response to the previous command.
7. Start a consumer to consume the tag location updates from the above topic by running the following command:

```
docker exec -it rtls_bitnami_kafka_container kafka-console-consumer.sh --
bootstrap-server

<kafka_broker_ip>:<port> -- topic rtls.tag_location_update.v2.json
```

8. To confirm that the system is operational, a steady stream of messages like those shown in Figure 12 should be seen on the Kafka consumer console.
9. Review the messages and verify that all tags are being reported and the location estimates look reasonable. It is recommended to move the tags throughout the coverage zone and verify that all tags are being read and their locations are being updated and reported.
10. Stop RTLS Services. To do this, cd to the rtls folder and run:

```
./rtls.sh -nk stop
```

Figure 12 Tag with Locations Being Reported on the Kafka Consumer Console


```
rpatil@rpatil-HP-Z440-Workstation: ~/kafka/kafka-docker
0,"confidence":50.00}}
{"message_id":1445,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:01.239+0000","position":{"x": 9
,"confidence":50.00}}
{"message_id":1446,"epc_id":"3175050952000030de000000","timestamp":"2018-07-20T10:47:05.104+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1447,"epc_id":"3175050952000030de000001","timestamp":"2018-07-20T10:47:05.108+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1448,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:06.141+0000","position":{"x": 9
,"confidence":50.00}}
{"message_id":1449,"epc_id":"3175050952000030de000000","timestamp":"2018-07-20T10:47:10.008+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1450,"epc_id":"3175050952000030de000001","timestamp":"2018-07-20T10:47:10.008+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1451,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:11.040+0000","position":{"x": 9
,"confidence":50.00}}
{"message_id":1452,"epc_id":"3175050952000030de000001","timestamp":"2018-07-20T10:47:15.160+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1453,"epc_id":"3175050952000030de000000","timestamp":"2018-07-20T10:47:15.161+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1454,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:16.192+0000","position":{"x": 9
,"confidence":50.00}}
{"message_id":1455,"epc_id":"3175050952000030de000000","timestamp":"2018-07-20T10:47:20.059+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1456,"epc_id":"3175050952000030de000001","timestamp":"2018-07-20T10:47:20.062+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1457,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:21.095+0000","position":{"x": 9
,"confidence":50.00}}
{"message_id":1458,"epc_id":"3175050952000030de000000","timestamp":"2018-07-20T10:47:25.216+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1459,"epc_id":"3175050952000030de000001","timestamp":"2018-07-20T10:47:25.225+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1460,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:26.002+0000","position":{"x": 9
,"confidence":50.00}}
{"message_id":1461,"epc_id":"3175050952000030de000001","timestamp":"2018-07-20T10:47:30.115+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1462,"epc_id":"3175050952000030de000000","timestamp":"2018-07-20T10:47:30.115+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1463,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:31.143+0000","position":{"x": 9
,"confidence":50.00}}
{"message_id":1464,"epc_id":"3175050952000030de000000","timestamp":"2018-07-20T10:47:35.015+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1465,"epc_id":"3175050952000030de000001","timestamp":"2018-07-20T10:47:35.016+0000","position":{"x": 1
0,"confidence":50.00}}
{"message_id":1466,"epc_id":"3175050952000030de000002","timestamp":"2018-07-20T10:47:36.047+0000","position":{"x": 9
,"confidence":50.00}}
```


Operational Validation: Static Testing

There are two methods for validating static location accuracy. The first method involves the use of reference tags placed in permanent, known locations. The second method involves the use of a denser, however, temporary grid of tags. Both reference tags and temporary grid tags have known tag IDs and their exact locations are precisely measured.

The following are guidelines for static testing of reference tags:

- Use a mid-large sized tag with read ranges of at least 25’ that are designed for industrial environments and can be permanently mounted. The Dura 1500 tag manufactured by Omni-ID has excellent read range and is optimized for mounting on metal.
- Reference tags should be encoded using the guidelines outlined in the ZAATS Tag Data and Numbering Guide, (p/n MN-003199-xx).
- Locate the tags at various heights and in areas where they will be minimally disturbed.
- Do not mount tags closer than 5’ to an ATR reader; mount the tags a minimum of 18” off the ground; and do not mount the tags such that the reported bearing to the closest ATR reader is higher than 55 º elevation; i.e., the 0º elevation beam is pointed at the floor (boresight beam) and the 90º elevation beam is

pointed at the horizon. For example, if a reference tag is mounted 6' off the floor, and the ATR readers are mounted at 16' off the floor, then the x-y distance from the reference tag to the closest ATR reader should be less than 15'. As another example, if the reference tag is mounted 18" off the floor, then the closest ATR reader mounted 16' off the floor should be no more than 21" away. This angle can be easily measured using handheld laser range finder devices.

- Use enough tags so that each ATR reader can reliably read at least one tag, preferably two. Also, ideally place the reference tags so that they are read by more than a single ATR reader.
- Record the exact x-y-z location of each reference tag (measured using the Disto 3D system) and store the information into the file ref_tag_info.csv.
- Use the built-in feature of the RTLS Demo Application to analyze and report the location accuracy statistics of the reference tags. See the RTLS Demo Application User Guide (p/n MN-003509-01) for more information on capturing accuracy statistics.

Using reference tags is a way to ensure proper operation and ongoing health of the RTLS system, even after handover to an end user. The RTLS system can be configured such that reference tag locations are monitored and a notification event is sent if the recorded locations deviate by greater than a configurable distance, typically 4'.

The use of reference tags is one method to validate the static location accuracy of the RTLS system. However, more tag location estimates are needed across the entire coverage area to ensure that the system fully meets the accuracy objectives specified during the requirement definition phase. Whereas the reference tags are permanent, the method described below is temporary, although, highly effective at ensuring proper system operation.

An example of a reference tag attached to a permanent metal object is illustrated in Figure 13.

Figure 13 Reference Tag Attached to Permanent Metal Object

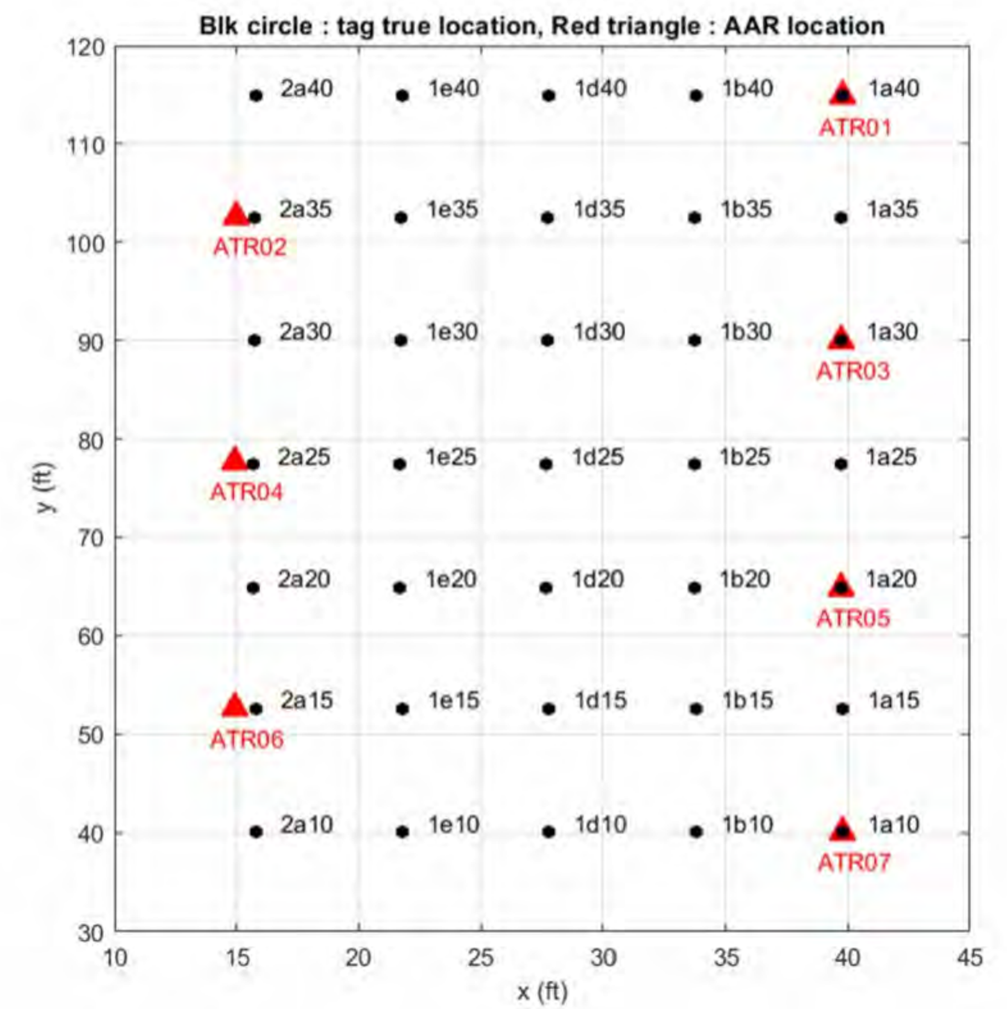
A second method for validating static location accuracy involves the use of RFID tags placed in a grid or array. The tags are surveyed with the DISTO system (See Appendix: Leica 3D Instructions for ATR7000) and their exact x-y-z locations recorded. The surveyed locations, also referred to as "ground truth", are then compared to the tag

locations estimated by the RTLS system. In this method, RFID tags are temporarily located within the coverage zone as shown in Figure 14.

The following are tips and guidelines for testing RTLS system operation with temporary grid tags:

- Use omni-directional tags with read ranges of at least 30’. The Zebra Sunrise RTLS tag is an excellent tag for this purpose.
- Grid tags should be encoded using the guidelines outline in the ZAATS Tag Data and Numbering Guide, (p/n MN-003199-xx)
- Locate the tags at heights between 2’ to 4’ off the floor.
- Place tags throughout the entire coverage zone, approximately 10-15’ apart.
- If it is not practical to cover the entire area in one step, the process can easily be broken up into multiple steps. Also, not every facility lends itself to such a uniform coverage of tags and certain trade offs will have to be made.
- The use of a measuring wheel is highly recommended to setup a grid of tags very quickly with reasonable precision.

Figure 14 Example of Grid Tags Used to Verify Static Location Accuracy with ATR Locations Superimposed



- To streamline the process, the origin of the grid can start directly underneath the known location of one ATR7000. Next, setup the tag grid relative to this known location using the measuring wheel to spot and

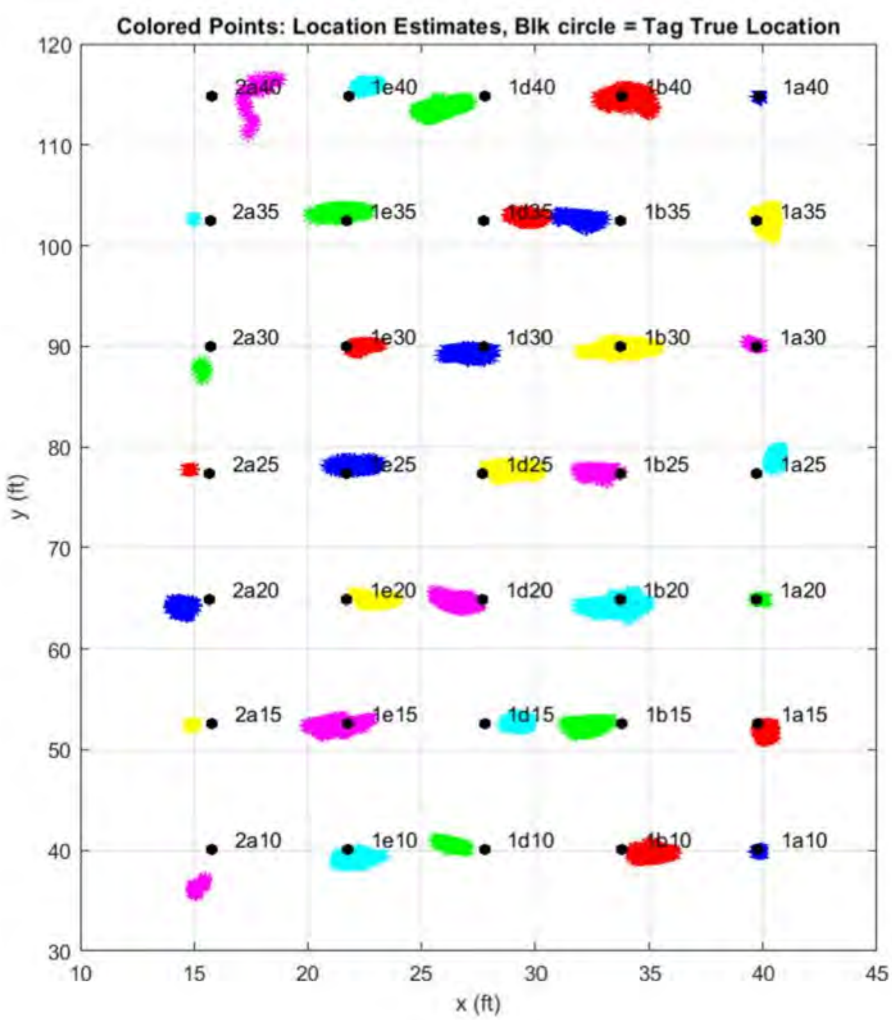
record the grid tag locations. Optionally, the Leica 3D Disto may be used for more precise grid tag locations for installations that require the highest levels of location accuracy.

- If it is not practical to cover the entire area in one step, the process can easily be broken up into multiple steps. Also, not every facility lends itself to such a uniform coverage of tags and certain trade offs will have to be made.
- Record the exact x-y-z location of each grid tag (measured using the Disto system) and store the information into the file grid_tag_info.csv.
- Use the built-in feature of the RTLS Demo Application to analyze and report the location accuracy statistics of the grid tags. See the RTLS Demo Application User Guide (p/n MN-003509-01) for more information on capturing accuracy statistics.

An example of tag location estimates for a typical ZAATS system, with coverage optimized for location accuracy is shown in Figure 15. A statistical analysis of this data reveals that 95% of the reported tag location estimates were within 4' of the actual location.

NOTE: It is important to ensure that 100% of the grid tags are reported by the RTLS system with no coverage holes.

Figure 15 Example of Grid Tags Used to Verify Static Location Accuracy



Operational Validation: Dynamic Testing

Once static location accuracy has been measured and validated, the final step in post-installation validation is to measure and validate the dynamic location accuracy of the system. Many of the same principles used to determine static location accuracy are employed for dynamic location accuracy. The procedure consists of establishing known fixed locations and moving one or several tags between the known locations, and then comparing “ground truth” to the locations estimated recorded.

Figure 16 illustrates a dynamic test procedure where the starting location is in front of the dock door labeled Door 1 and the ending location is in front of Door 18. The test is conducted where a tag is moved at close to constant speed between the known locations while the RTLS system is recording location estimates in real time. The test should be performed at two speeds, approximately 30-50% of the maximum anticipated speed and at 100% of the maximum anticipated speed. The former can be performed in the form of a walking test where a tag is walked at a constant pace between the known locations. In cases where multi-tagged items (forklifts, dollys, etc) are being tracked, the latter is ideally performed with the forklift, hand truck or dolly carrying the tagged items.

Figure 17 illustrates a second dynamic test procedure using a zig-zag pattern. As with the rectangular path, the test is conducted where a tag is moved at close to constant speed between known locations while the RTLS system is recording location estimates in real time. As before, the test should be performed at two speeds. In cases where multi-tagged items (forklifts, dollys, etc) are being tracked, the higher speed test is ideally performed with the forklift, hand truck, or dolly carrying the tagged items.

The following figures visualize these two testing procedures:

Figure 16 Example of Movement Pattern Used to Verify Dynamic Location Accuracy

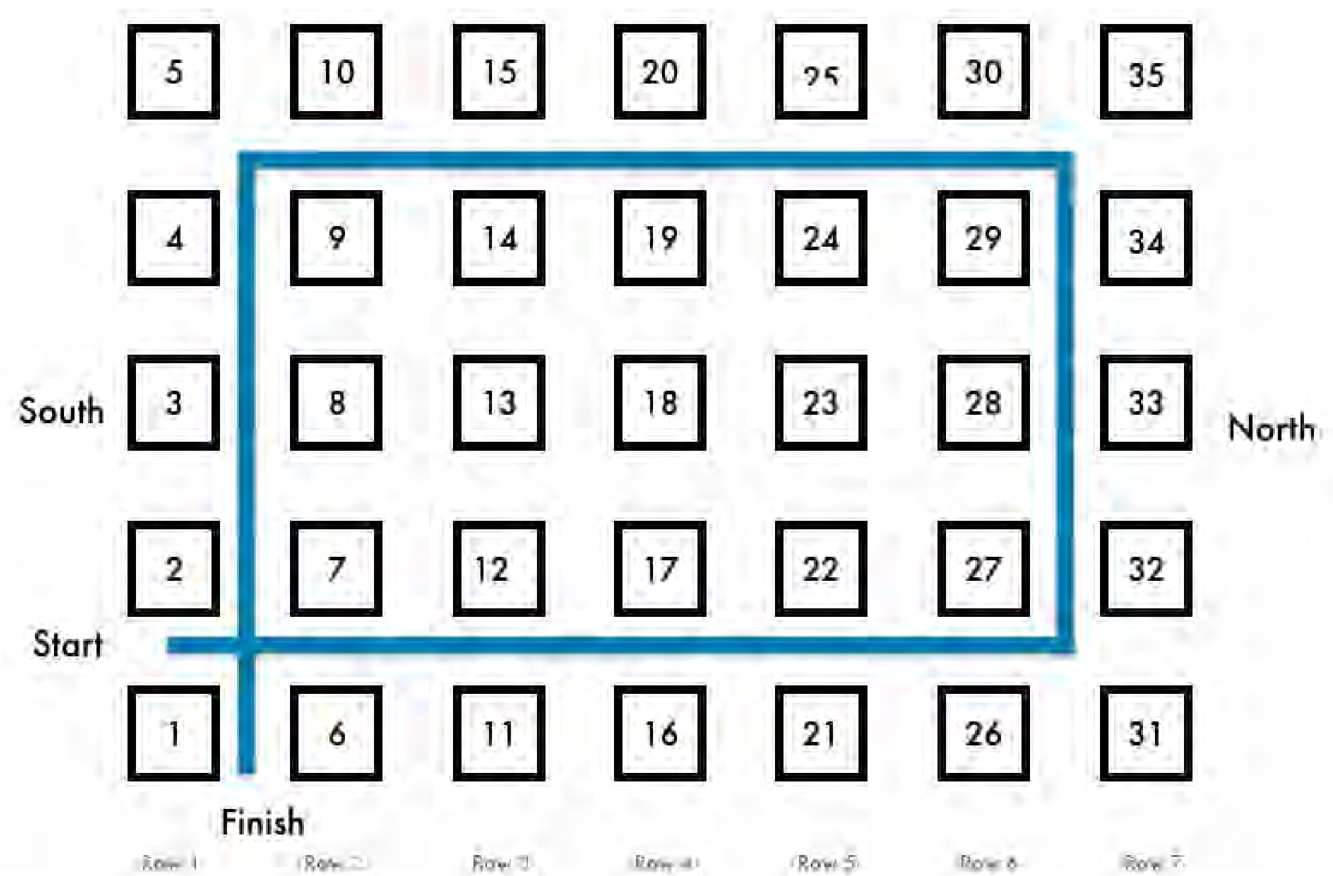
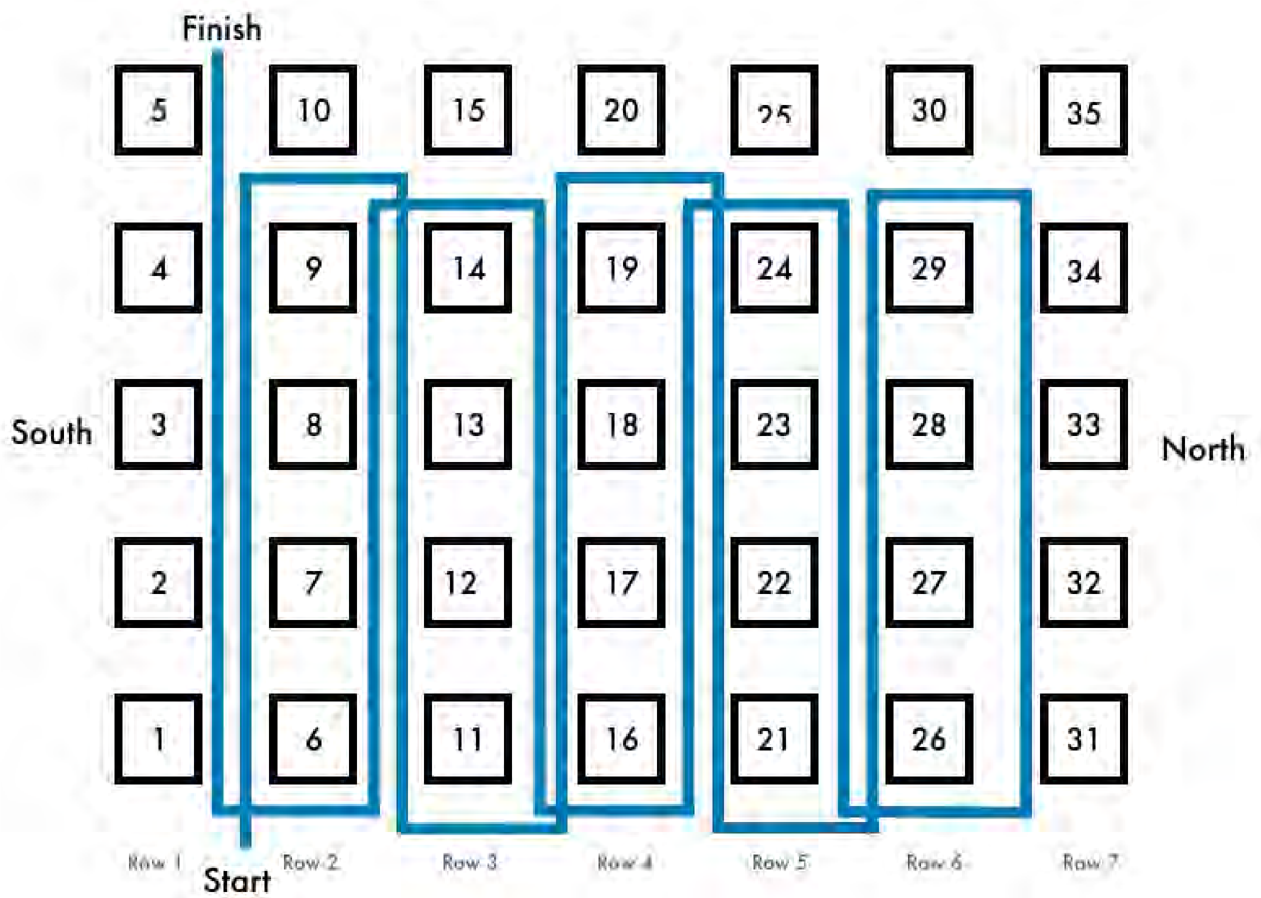


Figure 17 Example of Zig Zag Pattern Used to Verify Dynamic Location Accuracy



The following are tips and guidelines for dynamic testing:

- Use omni-directional tags with read ranges of at least 30‘ and encode tags using the guidelines outlined in the ZAATS Tag Data and Numbering Guide, (p/n MN-003199-xx).
- Locate the tags at heights between 2’ to 4’ off the floor.
- Endpoints should be situated such that tags are moved throughout the entire coverage zone.
- Record the exact x-y-z location of each endpoint (measured using the Disto system) and record the information into the file dyanmic_testi_info.csv.
- Use the built-in feature of the RTLS Demo Application to analyze and report the location accuracy statistics of the dynamic tags. See the RTLS Demo Application User Guide (p/n MN-003509-01) for more information on capturing accuracy statistics.

End User Handover

Prior to handover to an end user, the system designer/solution architect will review the validation test results and prepare a final report. Table 7 illustrates a template that can be used to summarize validation test coverage and location accuracy results that typically should be included in the report.

Depending on end-user specific requirements, there may be additional features and testing required; e.g. “multi-tag” testing, directionality testing, etc.

Table 7 Validation Test Results Template

General Test Conditions	**Date Tested:** **Location:** **Tested By:**				
Static Testing: Reference Tags - Coverage	Number of Tags	Percentage of Tags Read			
		Expected		Actual	
		100			
Static Testing: Reference Tags - Location Accuracy		R50		R95	
		Expected	Actual	Expected	Actual
		< 2.0’		< 4.0’	
Static Testing: Grid Tags - Coverage	Number of Tags	Percentage of Tags Read			
		Expected		Actual	
		100			
Static Testing: Grid Tags - Location Accuracy	Number of Tags	R50		R95	
		Expected	Actual	Expected	Actual
		< 2.0’		< 4.0’	
Dynamic Testing: Slow Speed - Location Accuracy	Number of Tags	R50		R95	
		Expected	Actual	Expected	Actual
		< 3.0’		< 5.0’	
Dynamic Testing: Fast Speed - Location Accuracy	Number of Tags	R50		R95	
		Expected	Actual	Expected	Actual
		< 4.0’		< 6.0’	

Depending on end-user specific requirements, there may be additional features and testing required; e.g. “multi-tag” testing, directionality testing, etc.

Appendix: Tools and Resources

Introduction

The following table summarizes tools and resources that are recommended for deploying a ZAATS system.

Tools and Resources

Table 8 Tools and Other Resources Used in a ZAATS Deployment

Tools	Supplier
General Tools	
Gloves	
Zip-Ties	
Plier Set	
Screwdriver Set	
Laser Level	
Wrench Set (Basic)	
Ratcheting Wrench Set (Recommended)	
Bosch GLM80 Laser Rangefinder (Basic)	
Leica E7400x Laser Rangefinder (Recommended)	
RFID Reader for Read Range Testing	Zebra RFD8500
USB RFID Reader for RFID Tag Programming	
Mounting Hardware	
Strut Channel 1 Foot Long	Available from McMaster
Clamps I-Beam	Available from McMaster
Channel Nuts 1/2-13	Available from McMaster

Tools	Supplier
Hex Nuts 1/2-13	Available from McMaster
Wave Disc Spring	Available from McMaster
Measuring and Layout, Advanced	
Laser Scanning Distance Meter	Leica 3D Disto
Aluminum Tripod	Leica CTP104D 790226
Self-Adhesive Target	Leica 780967
Measuring Wheel	Lufkin 12-1/2 in. Contractors Measuring Wheel
LED Flashlight	Medium to Large-sized with Adjustable Zoom Head
Binoculars	
Computer and Networking	
Managed PoE+ Gigabit Switch with SFP	Ubiquiti Networks EdgeSwitch or equivalent
WAN Router, with WiFI	CradlePoint IBR600C with LTE/HSPA+/EVDP Verizon
Cabling	
1000 Feet Bulk Cat6 STP Ethernet Cable - Solid Twisted Pair - Cat6 Shielded 550Mhz 24AWG Full Copper Wire Pull Box - In -Wall (CM), Blue	
Cat6, Cat5e RJ-45 Ethernet Cable Cap Connector Boots Plug Cover Strain Relief Boots (Blue)	
Cat6, Cat5e RJ-45 8P8C Ethernet Modular Crimp Connectors Plugs, pack of 100	
100 ft Cat6 Ethernet Cable - with RJ-45	
50 ft Cat6 Ethernet Cable - with RJ-45	
25 ft Cat6 Ethernet Cable - with RJ-45	
Ethernet Couplers, pack of 5	
Network Tool Repair Kit	SGILE Pro 9/1 (or equivalent)
Tone Generator and Probe Kit	Fluke Networks 26000900 Pro3000 (or equivalent)
8-Wire In-Line Modular Adapter with K-Plug	Fluke Networks 10230101 (or equivalent)

Appendix: Leica 3D Instructions for ATR7000

Introduction

This appendix describes step-by-step instructions to utilize a range finding device to obtain actual, ground-truth coordinates of the ATR readers, facility landmarks, reference tags, etc.

Detailed Steps

Location accuracy of the ZAATS system depends on having accurate coordinates ("ground truth") of the fixed facility landmarks, ATR readers, reference tags, and locations of static tags and walking path endpoints used during post-installation validation. The Leica 3D DISTO ™ , a cross between a surveyor's robotic total station and a hand-held laser distance measurer, can significantly enhance the accuracy and reduce the time required to perform these critical measurement tasks.

There are two ways to survey the ATR7000 readers, the bottom method (locating the center point of the antenna radome) or the side method (locating the z-reference point of the south face or north face of the reader). The side method is quicker, although, the bottom method is somewhat more accurate, depending on the skill level of the surveyor. Both methods are described below. Therefore, the angle from the Disto to the ATRs being measured should be 15 degrees or greater (referenced to the horizon). With this limitation in mind, depending on the installed height of the ATR7000 readers, one will be able to survey anywhere between 2-5 systems per Leica 3D Disto location using the bottom method or up to 10 systems using the side method before needing to relocate the Disto.

The steps involved with using a Leica 3D Disto for ATR7000 installation are outlined below:

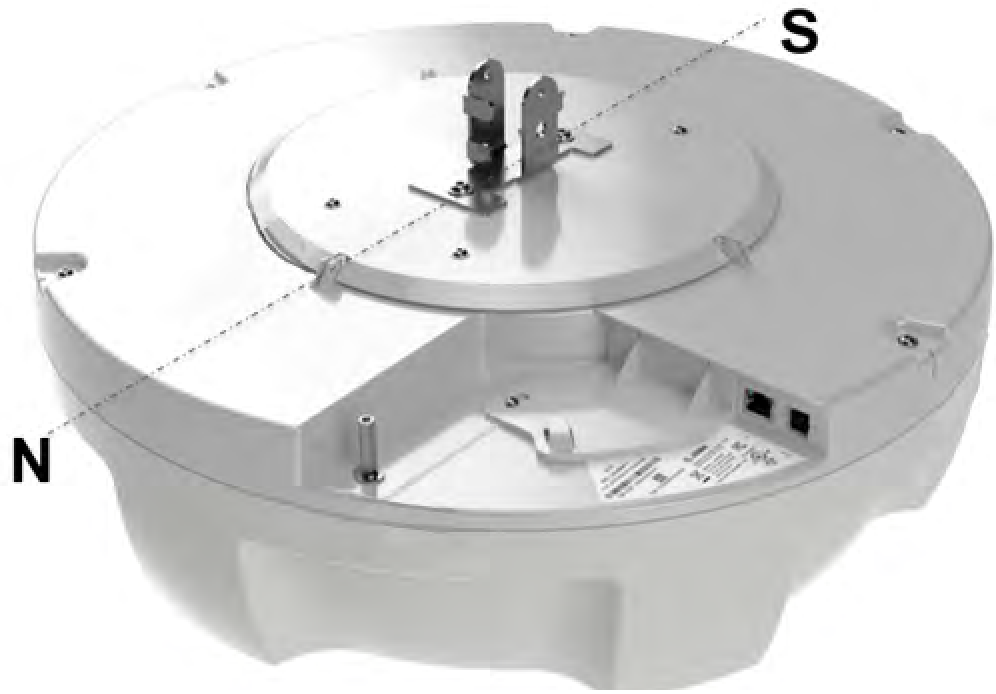
1. **Leica 3D Disto Familiarization.** Please refer to the extensive documentation and manuals available in the included CD with the Leica 3D Disto system or online (https://lasers.leica-geosystems.com/blog/3d-disto-manuals-documents) to gain familiarity with the Leica 3D Disto tool and procedures, and the operation of its software. Once the system documentation has been reviewed, it is highly recommended to practice with the system and software to gain further familiarity before heading to a live site where the system will be used.
2. **X,Y,Z (0,0,0) Origin Point.** The first step in surveying a newly installed deployment is establishing the site origin. The first point that the Leica 3D Disto system will measure is the z,y,z origin (0,0,0) point defined during the requirements phase. It is also important to have define the +x and +y directions used in the facility (which defines the reference "north" direction, etc. The 0,0,0 origin point should preferably be a "hard" building reference point (landmark) that cannot be moved, such as the corner of a building.

3. **Defining the X-axis.** The next point that the Leica 3D Disto system will measure defines the +x axis and direction. Measuring clockwise along a wall or floor from the origin point will be defined as the +x direction within the Leica software, and measuring counter-clockwise from the point of origin will be define as the -x direction in the Leica software. Note that it will be quite common to end up with a reversed coordinate system within the Leica software if it's not possible to survey in the preferred direction. This is not an issue and can simply be post-processed later.

4. **Relocating the Leica 3D Disto System**
   a. While 3 secure points are the bare minimum for a system relocation, it is highly recommended to use 4-5 secure points every time, both for the best possible relocation accuracy and as a safeguard against having an issue with a secure point that results in a failed re-location and then having to recover.
   b. The secure points, by definition, need to be visible to the system in both the previous and the relocated position.
   c. It is advantages in locations with higher ceilings to define several secure points on ceiling beams and structures, as these can easily be seen up high, and away from ground level structures and obstacles that can complicate the relocation procedure.
   d. The Leica #780967 self-adhesive target note will stick to most building surfaces, although some surfaces might need to be wiped down first.
   e. Although the Leica 3D Disto system can be used by a single person, a two-person surveying team, each familiar with the 3D Disto, will allow one to drive the 3D Disto system while the other counts ahead to set additional secure points for relocating the system as the surveying progresses through the facility. The extra team member can also help to spot alignment to secure points as the system measures them for relocation.

5. **ATR System Measurement**
   a. In the bottom method, aim the Leica 3D DIsto system at the bottom center of the antenna radome and note the x-y-z location. The x-y-z location is given by the actual measurement, however, the z location needs to be compensated. The reference z-axis height of the reader is defined as the position of the antenna ground plane relative to ground level. This position is located at the seam where the top cover meets the antenna radome, approximately 4.2" from the bottom of the radome. Thus, one will need to use the vertical offset tool in the Leica 3D Disto software. Measuring the bottom center of the radome and setting a -4.2" (-0.35') z-axis vertical offset will properly define and measure the z location of the ATR reader.
   b. The ATR7000 readers can also be surveyed from their sides. Locate the Leica 3D Disto system such that the South facing side of multiple ATR7000 readers can be observed from the survey point. Aim the Leica surveying system at a point exactly in the middle of the South side of the ATR7000 reader at the seam where the top cover meets the antenna radome. As before, this represents the position of the antenna ground plane and the true z-axis reference point of the reader. Next, use the offset tool of the Leica system software to compensate for the 9.5" difference between the south face of the reader and its center point (i.e. add +9.5" to the measured y-position of the south face). This will require greater care to spot accurately, however, it should allow a greater number of ATR7000 readers to be surveyed per location and allow more complete use of the Leica 3D Disto's long range capability. The same process can be applied, if needed, to then work from North to South along the next rows of ATR7000 readers, but this time targeting the direct North face of each system, and then applying a -9.5" y-axis offset to record the true center location. This method can also be used along the East-West axis of the system if the site layout favors this approach. Accordingly using a 9.5" offset in the +x or -x-axis direction to measure the system center as appropriate, as opposed to +/- y-axis offsets if surveying along the North-South axis.

Figure 18 Reference Orientation of the ATR7000 Reader



6. **Repeat steps 4-5 until all secure points, ATR7000 overhead readers, and permanent reference tags have been measured**. Also, capture x-y-z locations of temporary static tags and walking test endpoints used for post-installation validation. Figure X illustrates the output of the Leica 3D Disto Software in Snapshot View after the entire facility has been surveyed.
7. **Update the Equipment Manifest and Tag Reference File.** After surveying is complete, all measurements must be captured.
   a. View the recorded point for each ATR7000 reader and enter its x, y, and z-axis position into the Equipment Manifest file. This can be done through the graphical interface.
   b. If the Leica system had been recorded negative x and y-axis positions for the ATR7000 readers due to its software limitations, simply reverse their polarity back to positive by hand, if appropriate, while entering them into the manifest.
   c. Manifest example file:

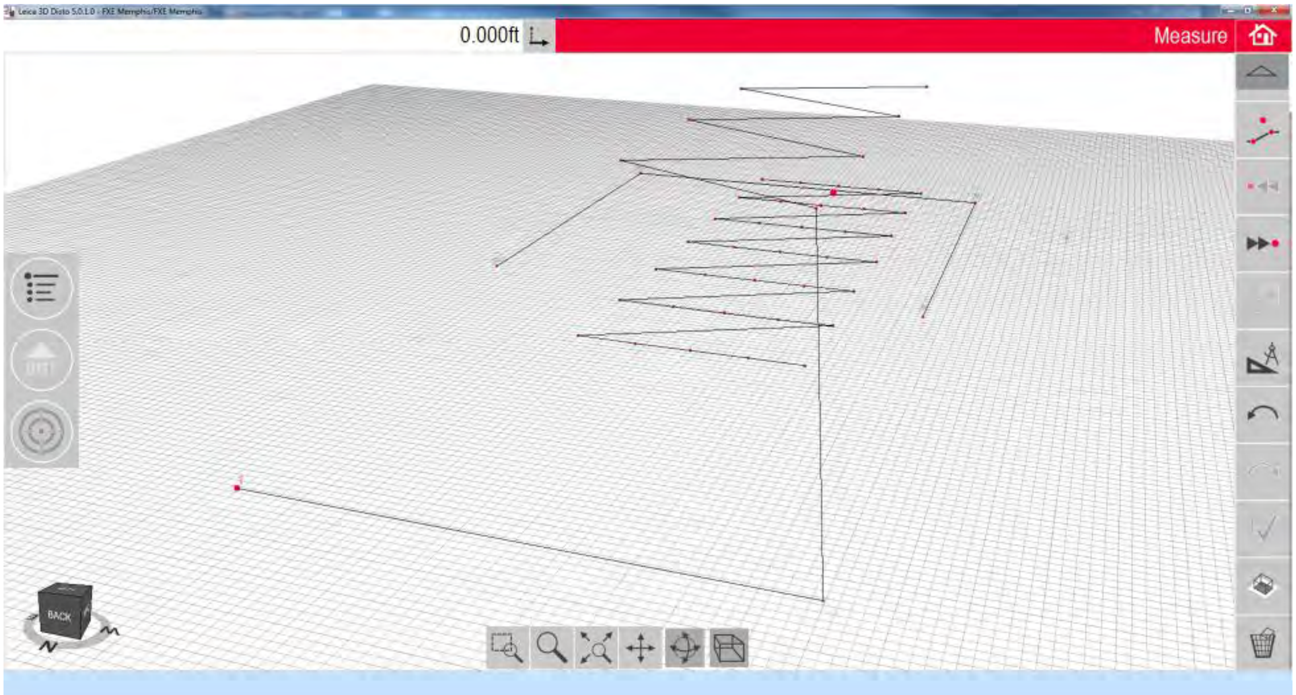
Figure 19 Manifest File

ATR Host Name	IP Address	X	Y	Z
ATR7000F36EC2	192.168.10.101	1.193	83.57	14.022
ATR7000F36986	192.168.10.102	13.712	71.917	13.964
ATR7000F36940	192.168.10.103	1.154	59.084	13.911
ATR7000F3695A	192.168.10.104	13.769	47.171	13.822
ATR7000F36E54	192.168.10.105	1.236	37.374	13.9
ATR7000F36A1D	192.168.10.106	13.1794	22.9	13.934
ATR7000F36A14	192.168.10.107	1.385	12.004	14.03

   d. View the recorded point for each reference tag and enter its x,y, and z-axis position into the tag reference file.

The steps described in this Appendix also apply to reference tags, temporary tags, dynamic test endpoints, etc.

Figure 20 Leica 3D Disto Software Snapshot View with Additional Text Annotations



Appendix: RFID Tag Board for ATR7000 Installation and Validation

Introduction

This appendix describes tag placement for testing the performance of an ATR upon installation.

Tag Board Construction Guidelines

In Preliminary Validation of the ATR7000 Readers and Basic Operational Verification (Optional) a test method was described that utilizes a tag board to ensure that readers are performing as expected after being installed when first powered up. The figure below illustrates one example of a tag board that will enable such testing.

Figure 21 Tag Board

In the figure above, the tag board is comprised of ZBR4000 tags (see Table 2) built on a ULINE S-11249 telescoping 16 x 16 x 40-74” box. The tags are placed in a pattern on the side of the box and placed approximately

three feet off the floor to ensure that a 45 degree beam from an ATR system will read the tags at the boundary of the reader's coverage area. Tags should be placed in alternating orientations (polarizations) and separated approximately 4-6 inches away from each other to avoid de-tuning the tags.

Tags used for individual element (400-413) testing must be placed 6-10 feet directly below the ATR reader being tested (see Preliminary Validation of the ATR7000 Readers); the top mounted tags serve this purpose. Both the top and side mounted tags are used for North/South/East/West testing of the ATR readers (see Basic Operational Verification (Optional)).